FINAL REPORT FOR Cooperative Agreement No.
INT-87262-COA with
MONTANA STATE UNIVERSITY
FS Contact: David Cole
MSU Contact: Clayton B. Marlow

The effects of packstock grazing on a dry, high elevation meadow

Final Report

December 4, 1991

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K M Olson-Rutz[1], C B Marlow[1], K Hansen[2], L C Gagnon[1], and R Rossi[3];
[1] Dept. Animal and Range Sci., [2] Dept. Earth Sci., Montana State University, Bozeman, MT 59717, [3] Dept. Statistics, Cal Poly, San Luis Obispo, CA 93407

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OBJECTIVE:

Grazing impacts are influenced by meadow type, handling method (picket, hobble, electric fence enclosure), and the duration, season, frequency within season, and yearly frequency of grazing. We examined the interaction between packstock grazing intensity, frequency and month of use on the stability of a high elevation meadow's soil and vegetation complex. We worked on a dry meadow with picketed horses to match common handling practices. Grazing duration and frequency were systematically increased to determine the level of use at which changes in meadow soil penetration resistance, ground cover and plant growth occur.

METHODS:

Study Site: We worked on the Burntfork of the Bacon Rind drainage in the Lee Metcalf Wilderness Area, southwestern Montana. The site is a dry upper timberline meadow, gently sloping to the southwest, at 2660 m elevation. The area is classified as *Festuca idahoensis/Agropyron caninum* habitat type (Mueggler and Stewart, 1980). Grass and forb species composition is in table 1. The meadow is used little by other packstock since there are no fishing opportunities and the area is closed to hunting. However, the meadow is used frequently by elk during parts of the summer.

Study Design:

1. One-time grazing. To study the effect of duration and month of a single grazing, we picketed horses for three durations (4, 8, and 18 hours) and had controls (0

Table 1. Vegetation composition of the meadow area grazed in 1988 based on percent of 2X5cm2 sampling frames containing the species in July 1988.

species	circle									
	1	2	3	4	5	6	7	8	9	Average
Grass/grass-like										
Agrcan	16.2	5.4	13.5	4.0	10.2	5.4	12.0	21.6	1.3	9.9
Bromar	1.3	0	2.7	0	0	0	0	0	0	0.4
Carex spp.	1.3	1.3	1.3	1.3	0	2.7	0	1.3	4.0	1.5
Fesida	10.8	5.4	8.1	5.4	14.3	13.5	0	2.7	13.5	8.2
Phlalp	2.7	2.7	1.3	0	2.0	1.3	0	0	0	1.1
Poaamp	0	4.0	0	1.3	0	0	0	1.3	2.7	1.0
Poafen	0	0	0	0	0	0	0	1.3	0	0.1
Poapra	0	2.7	0	0	2.0	6.8	4.0	1.3	2.7	2.3
Sticol	4.0	2.7	2.7	0	0	5.4	8.0	2.7	0	2.8
Trispi	2.7	1.3	1.3	0	0	2.7	8.0	9.5	0	2.8
Forbs										
Achmil	8.1	2.7	4.0	9.5	0	2.7	4.0	4.0	6.8	4.6
Arelin	0	1.3	1.3	5.4	0	0	0	0	0	0.9
Astragalus spp.	14.9	4.0	8.1	16.2	12.2	2.7	0	2.7	8.1	7.7
Delgey	0	0	0	0	4.1	0	0	0	0	0.4
Fraame	4.0	1.3	2.7	1.3	0	2.7	4.0	0	2.7	2.1
Lomatium spp.	1.3	1.3	0	0	0	0	0	0	0	0.3
Lupcan	0	0	1.3	0	0	0	0	0	0	0.1
Pedicularis spp.	0	4.0	0	0	0	1.3	0	0	0	0.6
Penstamon spp.	0	1.3	0	0	0	0	0	0	0	0.1
Polbis	0	1.3	0	0	0	0	0	0	0	0.1
Potgra	0	12.2	2.7	1.3	2.0	0	0	2.7	0	2.3
Taroff	0	1.3	0	1.3	0	0	0	0	1.3	0.4
unknown	29.7	35.1	36.5	33.8	44.9	48.6	52.0	44.6	55.4	42.3

hours) in each of three months (July, August, September). We had four replicate pickets per month for each duration. Horses were initially assigned randomly to treatment and replicate. When possible, the same horses were assigned to the same duration in subsequent months.

Duration, month, and replicate were randomly assigned to a picket circle. One set of picket circles was grazed in 1988 and another, new set, in 1989 on a different area of the meadow (Fig. 1). The 1989 circles were grazed again in 1990, each circle being grazed the same month and duration as the previous summer. The grazing schedule (Table 2) was determined day-light hours and by our sampling schedule which was dictated by inclement weather in 1988.

2. Repeat-grazing (JAS). To evaluate the influence of repeated grazing during one growing season we repeatedly grazed an additional set of circles in July, August, and September in 1989, and a new set of circles in 1990. Circles were consistently grazed for either four or eight hours in each month. Horses were randomly assigned to duration and replicate each month. The 1989 circles were interspersed among the one-time grazing circles, those added in 1990 were added on the edge of the existing circles (Fig. 1). The 1989 JAS circles were grazed again in 1990. Likewise the 1990 JAS circles were regrazed in 1991.

Vegetation and Soil Measurements:

Picket circles were 15 m diameter, based on commonly used picket rope lengths. Four transect lines (bearing N, S, E, W) were marked in each circle. At 30.5 cm intervals a 2x5 cm frame was placed perpendicular to the transect line. Twenty-five such frames were read on the N and S transects. Only the outer 3.8 m of the E and W transects were sampled to avoid a bias from more samples taken in the circles' centers. Before grazing the following data were collected from each frame:

a. percent cover - bare soil, rock, moss/lichen, litter, basal vegetation cover were estimated in 10% increments

b. stem counts - number of stems by grasses, forbs, and sedges separately

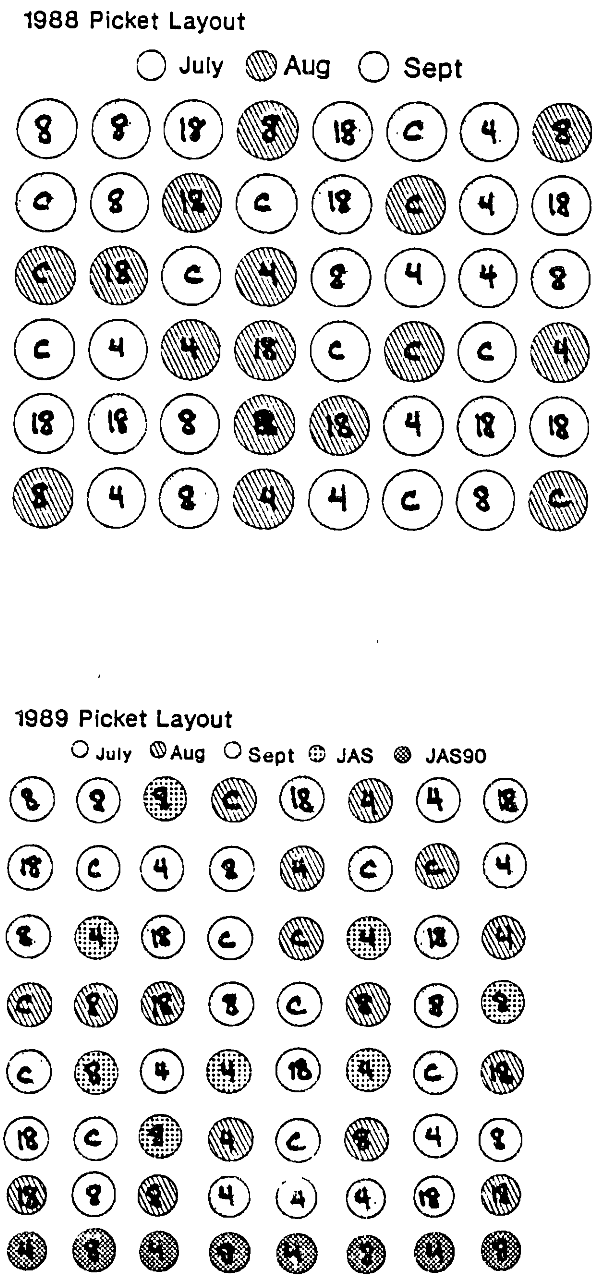

Fig. 1. The layout of treatment assignment to picket circles.

Table 2. Date and times of packstock picketing

Date	Hours Grazed	Picket Period 1 On	Picket Period 1 Off	Picket Period 2 On	Picket Period 2 Off
1988	0	n/a	n/a	n/a	n/a
	4	16:00	20:00	n/a	n/a
Jul 6 & 7	8	16:00	20:00	6:00	10:00
	18	16:00	1:00	6:00	15:00
	0	n/a	n/a	n/a	n/a
	4	11:00	15:00	n/a	n/a
Aug 17 & 18	8	7:00	11:00	17:00	21:00
	18	7:00	16:00	6:00	15:00
	0	n/a	n/a	n/a	n/a
	4	10:00	14:00	n/a	n/a
Sep 28 & 29	8	9:00	13:00	8:00	12:00
	18	7:00	16:00	6:00	15:00
1989	0	n/a	n/a	n/a	n/a
	4	16:00	20:00	n/a	n/a
Jul 20 & 21	8	6:00	10:00	16:00	20:00
	18	6:00	15:00	6:00	15:00
	JAS 4	8:00	12:00	n/a	n/a
	8	7:00	11:00	16:00	20:00
	0	n/a	n/a	n/a	n/a
Aug 15 & 16	4	15:00	19:00	n/a	n/a
	8	7:00	11:00	15:00	19:00
	18	7:00	16:00	7:00	16:00
	JAS 4	7:00	11:00	n/a	n/a
	8	7:00	11:00	15:00	19:00
	0	n/a	n/a	n/a	n/a
	4	14:30	18:30	n/a	n/a
Sep 13 & 14	8	7:30	11:30	14:30	18:30
	18	7:30	16:30	7:30	16:30
	JAS 4	7:30	11:30	n/a	n/a
	8	7:00	11:00	14:30	18:30
1990	0	n/a	n/a	n/a	n/a
	4	16:00	20:00	n/a	n/a
Jul 17-19	8	7:00	11:00	16:00	20:00
	18	7:15	17:00*	7:15	17:00*
	JAS 4	7:00	11:00	n/a	n/a
	8	7:30	11:30	16:00	20:00
	JAS90 4	16:00	20:00	n/a	n/a
	8	7:30	11:30	16:00	20:00
Aug 13-15	0	n/a	n/a	n/a	n/a
	4	18:00	22:00	n/a	n/a
	8	18:00	22:00	6:30	10:30
	18	6:15	17:00*	5:30	14:15*
	JAS 4	18:00	22:00	n/a	n/a
	8	15:30	19:30	6:00	10:00
	JAS90 4	6:00	10:00	n/a	n/a
	8	6:00	10:00	16:30	20:30
Sep 10 -12	0	n/a	n/a	n/a	n/a
	4	18:00	22:00	n/a	n/a
	8	18:15	22:15	7:00	11:00
	18	7:15	16:45*	5:30	14:45*
	JAS 4	18:30	22:30	n/a	n/a
	8	15:00	19:00	5:30	9:30
	JAS90 4	5:00	9:00	n/a	n/a
	8	7:00	11:00	15:00	19:00
1991	JAS90 4	18:00	22:00	n/a	n/a
	8	18:15	22:15	6:30	10:30
Jul 15 & 16					
Aug 12 & 13	JAS90 4	18:00	22:00	n/a	n/a
	8	18:15	22:15	6:15	10:15
Sep 6 & 7	JAS90 4	17:30	21:30	n/a	n/a
	8	17:30	21:30	7:00	11:00

*extra time allowed for watering during the 9 hour period
n/a = not applicable

c. vegetation height - the height class of the tallest plant material of only the dominant (according to stem count) vegetation type was recorded in 1988. Height classes were recorded separately for grasses and forbs in subsequent years. Height classes were as follows;

class 0 = no plants or those lower than the frame (0.25 cm)
1 = 0.25-2 cm
2 = 2-4 cm
3 = 4-12 cm
4 = 12-24 cm
5 = 24+ cm

d. grazed plant frequency - for grass and forb separately, we noted whether the plants were grazed. These data were not taken in 1988.

e. soil surface compaction - we used a pocket ring penetrometer, which only measures penetration resistance in the top 1 cm soil layer. In 1988 we measured five points along the N and S transects and three points along the E and W transects at 1.5 m intervals (n=16 per circle). In all other years compaction was measured at each frame location (n=76 per circle).

After grazing we remeasured plant height class, grazed plant frequency, and soil surface penetration resistance. We took photographs of each circle and counted manure piles by species (horse, elk, deer) in each circle before and after grazing. We also collected a 20 cm soil core at the outer end of each vegetation transect to determine soil moisture. In September 1988 it snowed six inches the first night and we could not measure all the circles before grazing. Therefore, those data are incomplete.

The circles grazed in 1988 were reread in August 1989, those grazed in 1989 were reread in July 1990, and again in July 1991 to determine the influence of grazing on the soil and vegetation the following growing season.

The repeat-grazing circles (JAS) were measured in the same way. However, in August and September, pregrazing data included only height class, grazed plant frequency, and soil surface compaction, and not percent cover and stem counts. The JAS circles established in 1990 and grazed in 1990 and 1991 will be reread in 1992.

Horse Behavior:

Horses were only allowed to graze (hobbled or in electric fence enclosures) until the evening before their scheduled picketing time. Otherwise they were kept on a hitch line near camp. The 4-hour horses were on the picket for four consecutive hours. The 8- and 18-hour horses were picketed for two four and nine hour periods respectively (Table 2).

Behavior was quantified in 1988 and 1989 to aid in understanding the potential ecological impact of picketed horses. Observations began ½ hour after horses were put on the picket. Horses were observed for 15 continuous seconds every five minutes for the next ½ hour. The ½ hour observation periods were alternated with ½ hour of no observations for as long as horses were on pickets. During each 15 second observation, we noted the following: a) whether the horse was grazing, traveling, or standing and resting, b) the number of grazing stations used - grazing stations are foraging locations separated by two or more front leg steps, and c) location in the circle (center, middle, edge). In July 1988, the 18-hour horses spent part of their first period on the picket in the dark, and behavior observations could not be made. Therefore a portion of those data are missing.

Data Analyses:

1. Vegetation: All data were summarized to a mean value per circle, since the circle is the replicate sample unit. We calculated the proportion of frames in each height class and of the frames with vegetation, the proportion with grazed plants. We used an arcsine-squareroot transformation to normalize the distribution of cover, height class, and grazed proportions. Stem counts were analyzed as mean counts per vegetation type. We used $\alpha = 0.10$ for all tests.

a) To quantify the immediate impacts of grazing, we analyzed post minus pregrazing values of height class, soil compaction, and grazed plant frequency data. Data were analyzed as an analysis of covariance, with month, duration, replication within duration, and month by duration as independent factors. Where data were available for grasses and forbs separately, the vegetation types were compared for differential use.

Proportion of rock, soil, and litter cover were included as covariates in soil compaction analyses. Soil moisture was not included because it was measured over a 20

cm depth, whereas the penetrometer only measured compaction in the top 1 cm. Pregrazing soil compaction and soil moisture were included as covariates in the plant height class analyses.

b) To determine the influence of duration, frequency and month of grazing one year on the plant community and soil the following growing season we remeasured all circles one year after grazing.

To account for initial differences among circles, before grazing, we should analyze the difference between one year later and initial values. However, since the span between initial measurements and one year later was different for each month and among years we could only compare durations within a month. This reduces statistical power and makes grazing duration and month comparisons difficult to understand. To adjust for these inequities we calculated a modified index of change used by Cole (1987).

$$Y_i = \left[\left(\frac{\text{final Y on grazed}}{\text{init. Y on grazed}} \right) \times \left(\frac{\text{init. Y on control}}{\text{final Y on control}} \right) \right] - 1 \times 100$$

We used the mean value of (init. Y control/final Y control) from the ungrazed circles corresponding with the grazed circles. By subtracting '1' from the product the sign of Y_i indicates the direction of deviation from the controls. A negative Y_i implies the treatment decreased relative to the control, a positive sign implies increase. Models used for AOV were the same as for immediate impacts, but without covariates.

When treatments are not found to be different, it can imply two things: 1) there is actually no treatment effect, or, 2) the sampling design is not sensitive enough to detect treatment differences. Therefore, we calculated power curves for some data. These estimate the magnitude of difference necessary among treatments for us to detect a treatment effect with 75% probability ($\beta = 0.25$).

2. <u>Horse Behavior:</u> From the behavior observations we calculated the proportion of observations per hour in which the horses grazed, traveled or rested. More than one behavior could be recorded per 15 second observation period. Therefore, the proportions calculated for the three behaviors did not always add to 1.0. We also calculated the hourly mean number of grazing stations during the 15 second observation period. Treatment means of these variables were compared using analysis of variance.

The behaviors were plotted over time to visually look for patterns in the behaviors. We estimated correlation coefficients between grazing and resting and used linear regression to evaluate postgrazing soil compaction as a function of time spent traveling.

To determine if we could predict hours of grazing available on a meadow, we compared grazed plant frequency with actual hours spent grazing rather than the duration of time on the picket and pregrazing plant height by regression.

RESULTS and DISCUSSION:

Vegetation:

1. Before Grazing:

a) Percent Cover:

Within a month, all circles were the same for each cover type before grazing in both 1988 and 1989 (Fig. 2). There was more moss and vegetation and less soil in July than in August 1988. Because of the 1988 drought, grasses and forbs were brittle, and moss had dried out by August. Thus, there was a premature shift from standing vegetation to litter and soil. Again, the September data are incomplete because of snowfall. In 1989, a non-drought year, none of the cover types changed through the summer.

b) Plant Height Class Distribution:

In 1988, before grazing, the proportion of plants in height classes 1 and 2 were the same in July and August. Yet, in July there were more plants in height 3 and less in height 0 (not shown) than August (Fig. 3a). 1988 was a dry year and the taller leaves (height 3) had broken off by August, leaving no measurable rooted vegetation (height 0). Because of an overnight snowfall we could not measure all of September's circles. Therefore, September data are incomplete.

Since plant height was recorded separately for grasses and forbs in 1989 we cannot quantify the overall vegetation height class distribution that year.

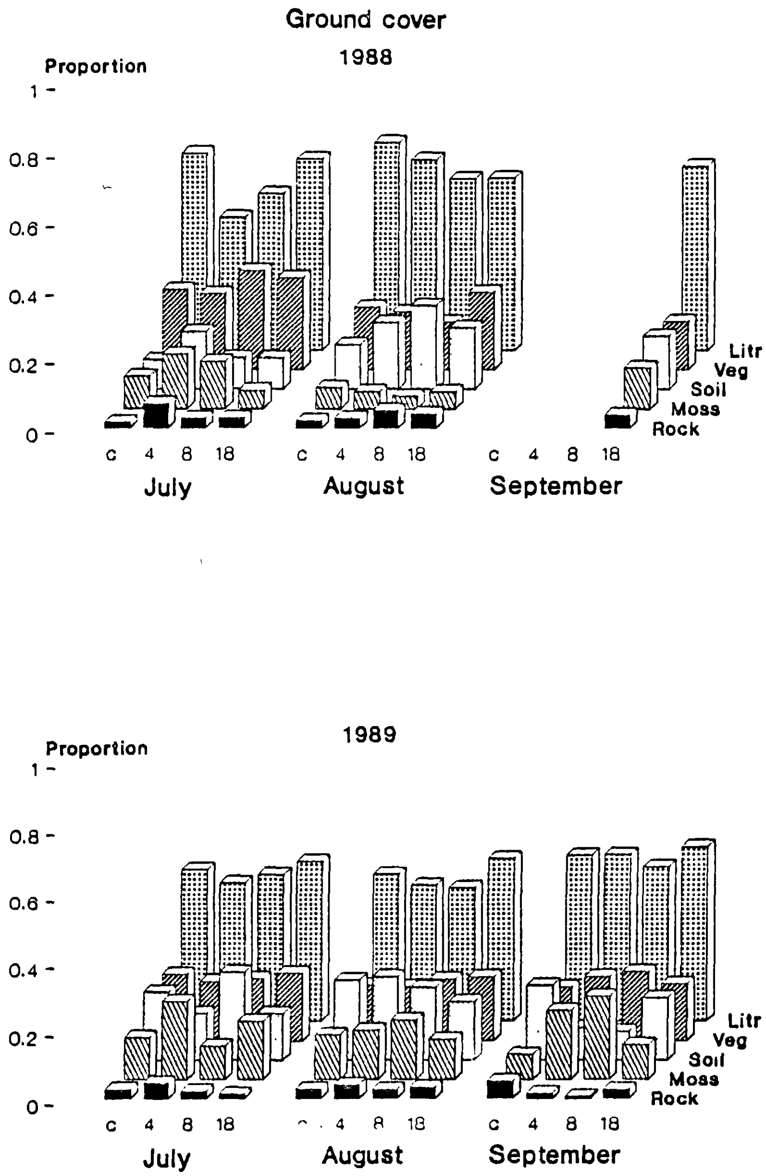

Fig. 2. Monthly basal cover before grazing on the 1988 (a) and 1989 (b) meadows.

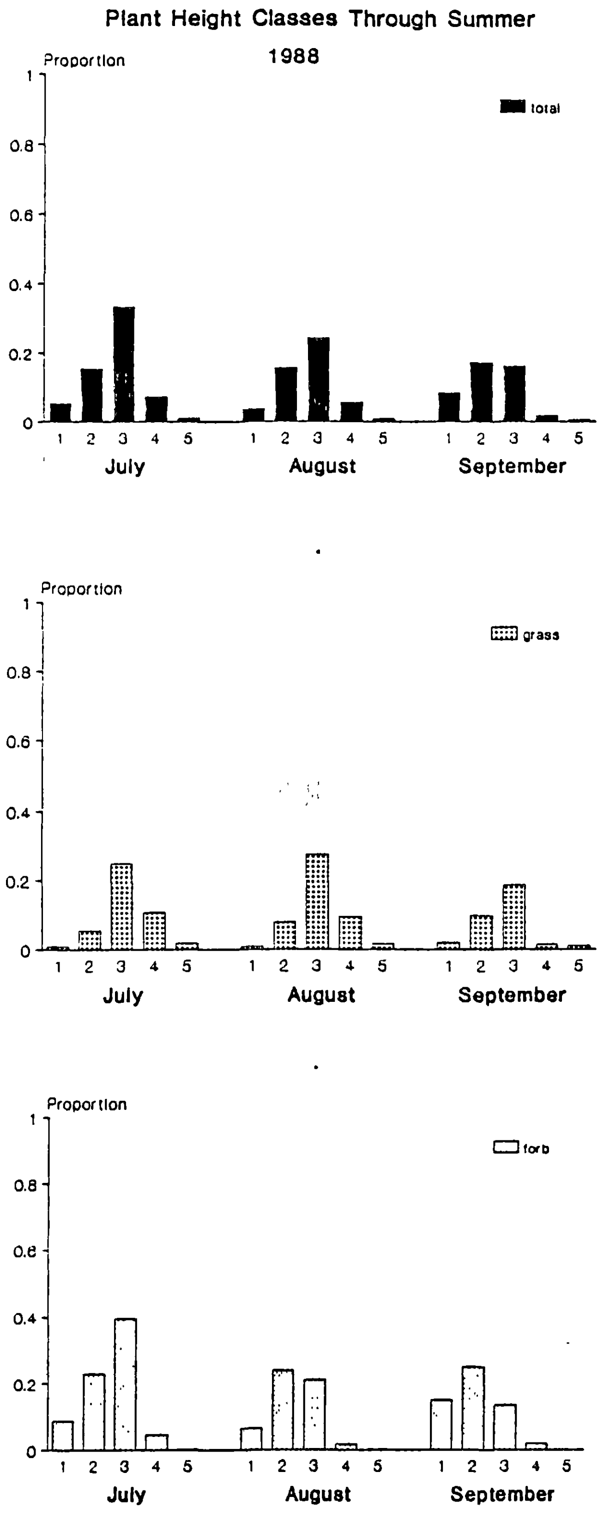

Fig. 3. Monthly plant height distribution before grazing on the 1988 meadow a) all vegetation, b) grasses, and c) forbs.

In both years there were consistently more forbs than grasses in classes 1 and 2, whereas grasses dominated classes 4 and 5. Grasses and forbs were equally present in height 3, except in August 1988 and September 1989 (Fig. 3b,c, Fig. 4a,b). Forbs were shorter at those times because many had senesced and the leaves broken off (classes 1 and 2). The general pattern from July to September is a progression towards a more uniform, but shorter stature vegetation. The dry climate in 1988 hastened this process.

c) Grass and Forb Stem Counts:

In 1988 there were more forb than grass stems in July (Fig. 5a). However, by August there were equal or fewer forb than grass stems. By August the forbs had dried and broken off, which agrees with the increase in height class 0 found in August. September data were incomplete. The higher forb count is also reflected in the higher forb frequency described in Table 1.

Although not as pronounced, the same change through the summer was evident in 1989 (Fig. 5b). Forb and grass stem numbers were equal and consistent from July through August. By September the number of forb stems had declined and grass stems increased slightly, as noted in August 1988. However, unlike in 1988, there is not a concomitant increase in height class 0. Therefore the forb stems had not broken off and "disappeared". This change in stem counts may be an artifact of the sampling method. In July and August, many forbs are in a rosette stage and leaves appear to go directly into the ground. Therefore they are counted as stems. However, by September most forbs have bolted which elevates many leaves and fewer are counted as stems, giving us a reduced stem count in September.

On the 1989 meadow, soil moisture influenced stem counts. The moist circles had more grass stems than the dry ones (Fig. 6a), whereas forb stem density was not influenced by the moisture gradient found on this meadow (Fig. 6b).

Since grass and forb stem counts change differently through the summer, it is important that grazed circles be compared with an ungrazed circle, sampled at the same time, to eliminate seasonal bias.

d) Soil Surface Penetration Resistance:

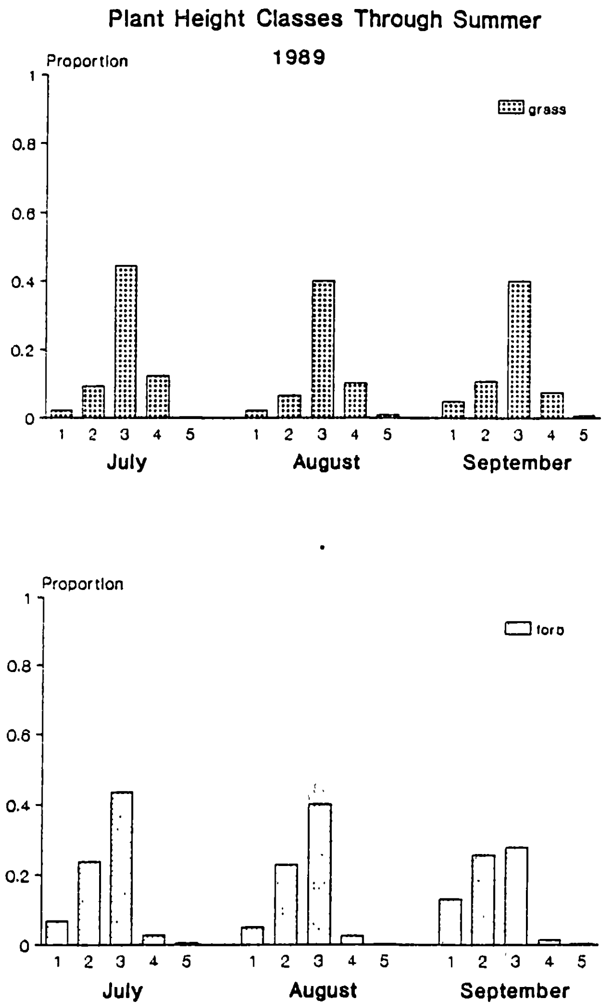

Fig. 4. Monthly plant height distribution before grazing on the 1989 meadow a) grasses, and b) forbs.

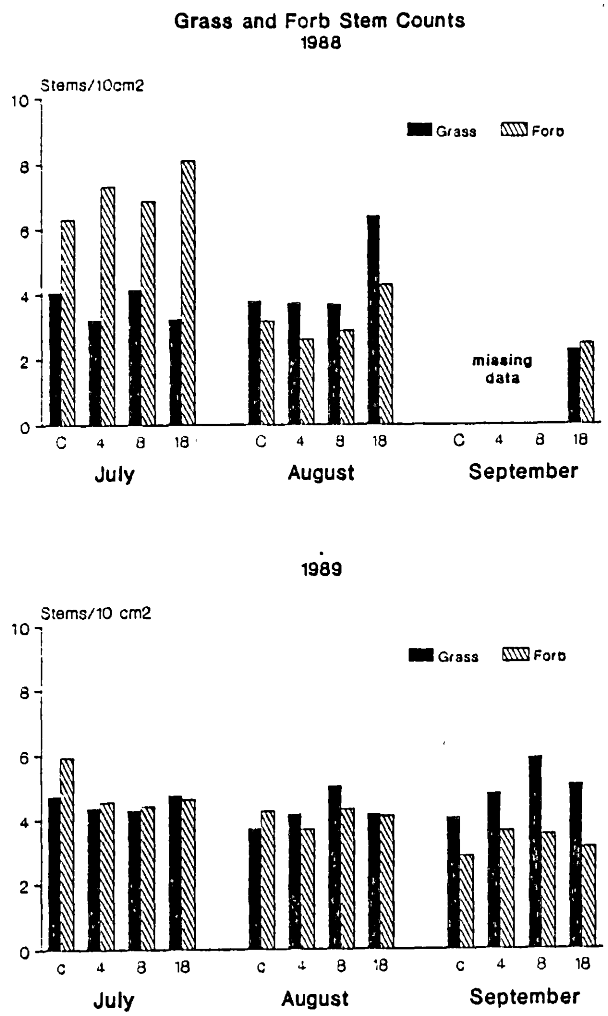

Fig. 5. Monthly grass and forb stem counts before grazing on the 1988 (a) and 1989 (b) meadows.

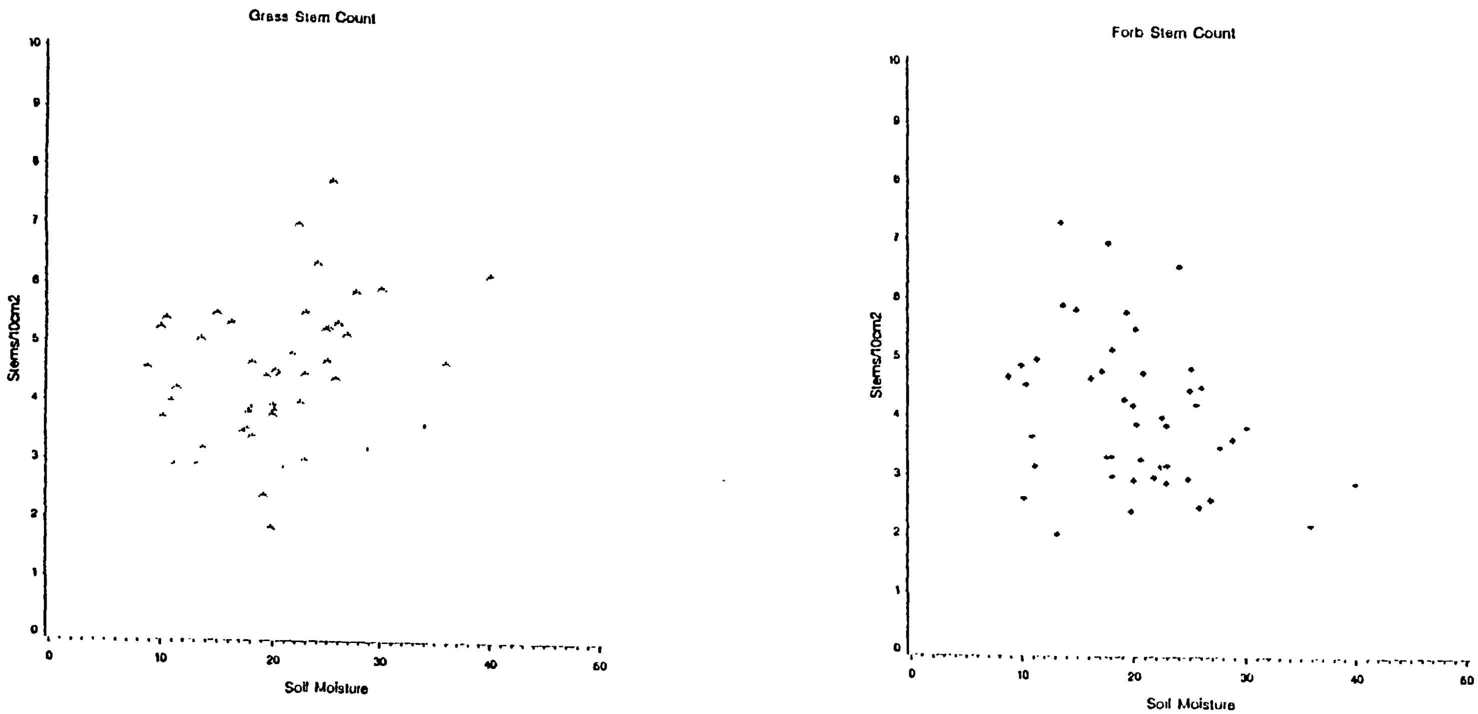

Fig. 6. Grass (a) and forb (b) stem counts relative to soil moisture.

The soils were less compact in July than in August 1988 (Fig. 7a). By August the surface soil layer was dry and hard. September's snowfall precluded pregrazing soil compaction measurements. In contrast to 1988, we had periodic summer rains in 1989 and soil compaction measurements were consistent throughout the summer (Fig. 7b).

e) Grazed Plant Frequency:

In 1989 and 1990 we recorded the frequency of plants grazed before (and after) horses were put on the picket circle. These pregrazing data allowed us to assess the intensity of elk grazing on this meadow. In 1989 elk use declined as the summer progressed, and they preferred grasses over forbs (Table 3). The pattern of use was different in 1990. There was an increase in elk grazing by September and there did not appear to be a preferential use of grasses over forbs.

Table 3. Percent of grasses and forbs grazed before picketing horses (means ± stderr).

Year	Month	Forb	Grass
1989	Jul	10.6±3.9	25.3±6.7
	Aug	9.3±1.3	20.8±1.9
	Sep	4.9±1.0	14.8±2.8
1990	Jul	8.7±1.3	7.9±1.1
	Aug	10.7±1.8	9.9±1.5
	Sep	13.5±2.3	17.5±3.2

These changes in the plant community through the summer and from year to year reinforce the importance of measuring controls at the same time as treatments to avoid confounding treatment effects with seasonal or yearly effects. The pregrazing characteristics of the meadow in 1990 are not discussed since they may be a reflection of the previous summer's grazing treatments.

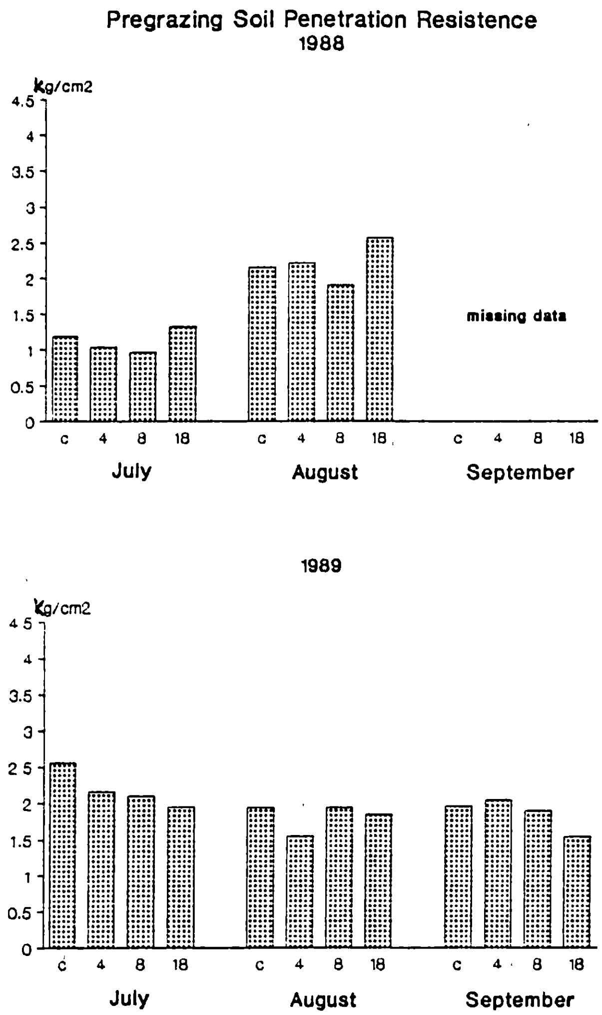

Fig. 7. Monthly pregrazing soil compaction on the 1988 (a) and 1989 (b) meadows.

2. Immediate Impact:

Immediately after horse grazing we remeasured plant heights, soil surface compaction and grazed plant frequency (1989 only). With these data we were able quantify the immediate changes to the soil and vegetation as a result of horse grazing.

a) Plant Height Class Distribution:

In 1988 variation among replicate circles within durations made it difficult to detect postgrazing differences in height classes among the four grazing durations. We had to have greater than 15-25% differences in the proportion of plants in a given height class among the grazing durations to find the durations statistically different. However, there was a pattern of increase in the lower height classes with concomitant decreases in tall plant numbers which became more pronounced with longer grazing durations (Fig. 8a).

In 1989 heights were measured separately for grasses and forbs. As in 1988, there was a general pattern of shift from taller to lower plants with increasing grazing duration. This shift was stronger for the grasses than forbs (Fig. 8b,c). Unlike the longer grazing periods of 8 and 18 hours, four hours of grazing produced a negligible change in height class distributions.

In 1990 the proportion of grasses in height classes 1 and 2 increased after eight and 18 hours grazing (Fig. 8-2a). Four hours caused little change. Unlike in 1989, the forbs changed very little in height class distribution even after 18 hours grazing (Fig. 8-2b). This could be because 1990 was a more productive forb year. Comparison of the height class distribution of the control circles indicates 1990 had more tall plants of both grasses and forbs than 1989.

The circles were less variable in 1989 and 1990 than 1988. Therefore the data were sensitive enough to detect differences in a range of 0.005 to 0.02 among durations, months, and vegetation types. However, since there are so many variables (height class, duration, month, vegetation type), detailed description of statistical differences are not presented here.

The cumulative impact of repeated grazing through the summer (JAS) on plant height class distribution is depicted in figure 9. By the end of the summer

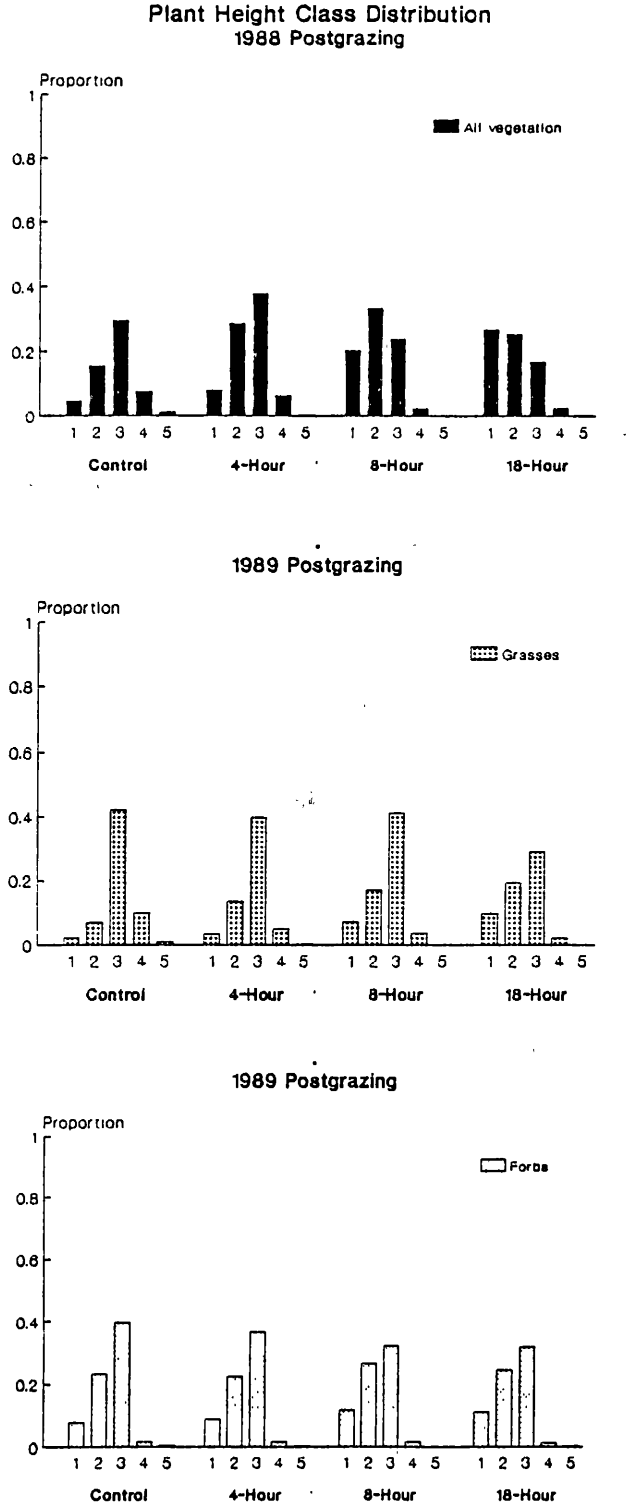

Fig. 8. Plant height distribution of a) all vegetation combined after grazing on the ungrazed, 4-, 8-, and 18-hour circles in 1988, b) grasses and sedges in 1989, and c) forbs 1989.

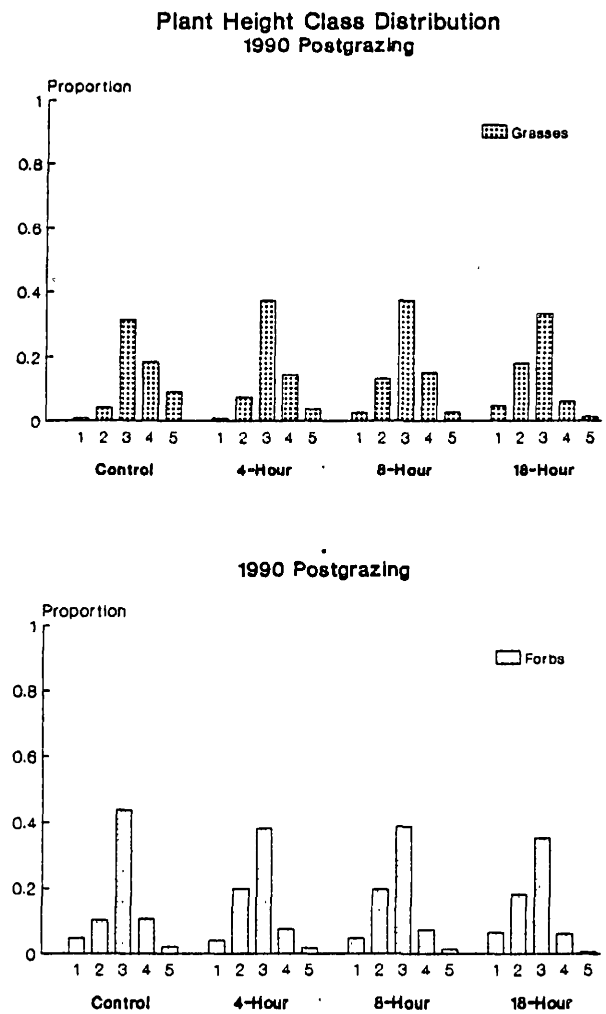

Fig. 8-2. Plant height distribution of a) grasses and b) forbs after grazing on the ungrazed, 4-, 8-, and 18-hour circles in 1990.

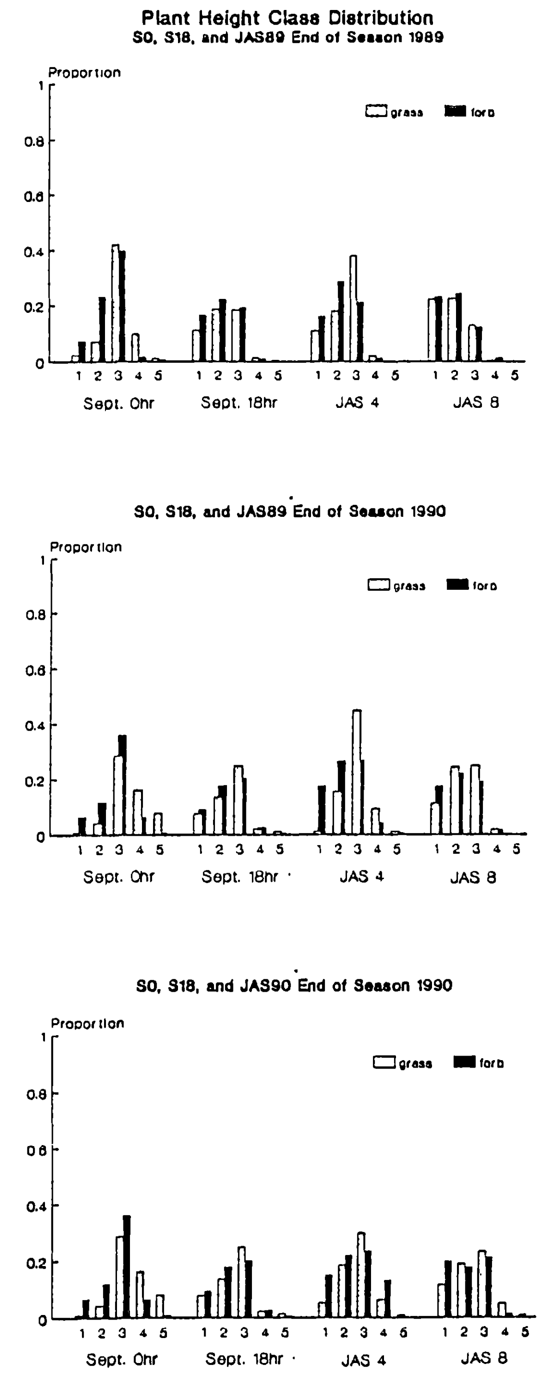

Fig. 9. Cumulative impact of repeated grazing on plant height distribution by the end of the grazing season a) 1989, b) 1989 circles grazed in 1990, and c) JAS90 circles grazed in 1990.

the JAS 8-hour circles had few plants taller than 12 cm and resembled the one time 18-hour grazed circles. After repeated grazing the grasses and forbs in the 8-hour circles appeared to have the same height class distribution. In contrast, although repeated four hours of grazing did reduce both grasses and forb heights we could still locate grasses in most sampling frames taller than 4 cm, whereas most forbs were shorter than 4 cm. This can be misleading, since the controls also had a greater proportion of forbs in smaller height classes and we measured the tallest remaining plant material rather than average plant height.

b) Grazed Plant Frequency:

By calculating the post minus pregrazing change, we accounted for prior use by elk. These data were not collected in 1988. In 1989 the grasses were grazed more than the forbs under all durations of grazing (Table 4). The percent of grasses grazed increased with duration on the picket. Use of forbs was the same after 4- and 8-hours grazing, but increased with 18-hours of use. This indicates that horses will begin to use forbs when forced to, by spending longer times on the picket. The pattern was similar in 1990, except that fewer plants were grazed.

Table 4. Percent of grasses and forbs grazed by picketed horses.

Plant type	Hours grazed	Grass	Forb
1989	4	27.4	13.6
	8	41.9	13.9
	18	54.7	25.8
1990	4	17.2	5.4
	8	30.9	7.9
	18	40.4	19.2

On the repeatedly grazed circles (JAS) in 1989 and 1990 the cumulative impact of 4-, and 8-hours grazing through the summer was equivalent to one time 8-, and 18-hours grazing respectively, on grasses and forbs (Figs. 10a,b and 11a,b). The pattern on the JAS90 circles was a little different. On these circles the cumulative impact of 4- and 8-hours grazing was the same. Both durations grazed grasses to a one-time 18-hour grazing level, and forbs to a one-time 8-hour level (Fig. 12a,b). Since we were not grazing any circles only once in 1991, there are none to compare with the JAS90 circles. However, the cumulative impact by end of season was high after 4- and 8-hours grazing (Fig. 13a,b). The grasses consistently received heavier use. On two of the 8-hour circles 100% of the grasses sampled had been defoliated.

c) Soil Surface Penetration Resistance:

In 1988, 18 hours of grazing increased compaction by 0.6 kg/cm^2 in July and decreased compaction by 0.4 kg/cm^2 in August (Fig. 14a, the possible range is 0 to 4.5 kg/cm^2). The soils were still moist and could be compressed in July. By August, soils were dry and hard. Hoof action created dust piles, which resulted in lower compaction readings. Soil surface compaction was not measurably affected by the shorter grazing durations.

In 1989 only the July 4- and 8-hour, and the September 8- and 18-hour durations had significant increases in penetration resistance (Fig. 14b). Of these, only the September 18-hour duration increased more than 0.5 kg/cm^2.

With the exception of July and September 4-hour circles all grazed circles in 1990 had an immediate change in soil penetration resistance with grazing (Fig. 14c). August's and September's circles increased, but July's decreased. This is because we had rain between pregrazing and postgrazing measurements in July. Very moist soil surfaces have little penetration resistance.

Despite these immediate changes in soil surface compaction, soil density equaled that of the ungrazed circles within one month after grazing in 1988, 1989, and 1990 (Fig. 15a,b,c).

Although there appeared to be immediate changes in penetration resistance each month of the repeatedly grazed circles (JAS and JAS90), there was no cumulative effect (Fig. 16a,b,c). The change from pregrazing in July to postgrazing in September was not significantly different between the grazed and

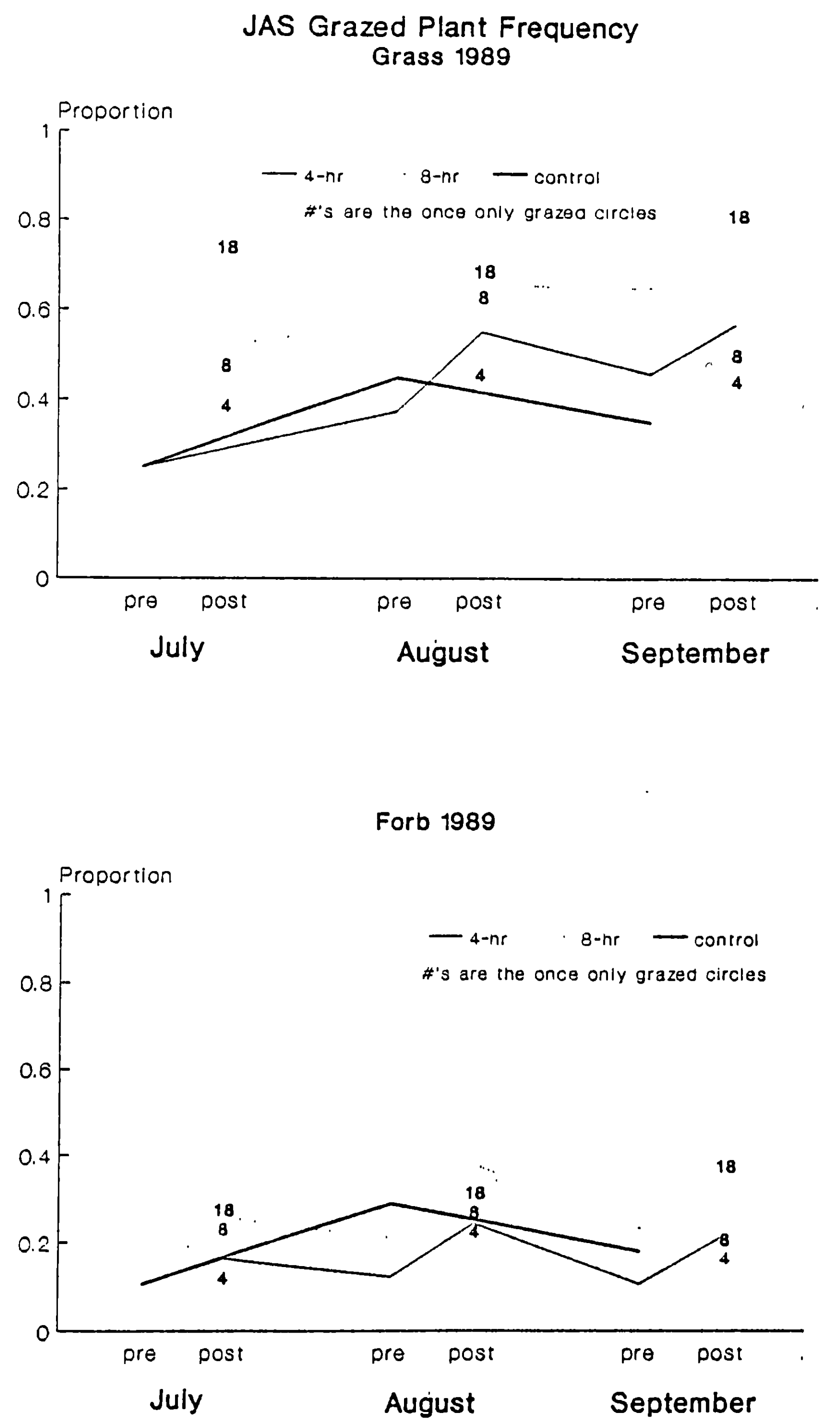

Fig. 10. 1989 grass (a) and forb (b) grazed plant frequency on the repeatedly grazed circles.

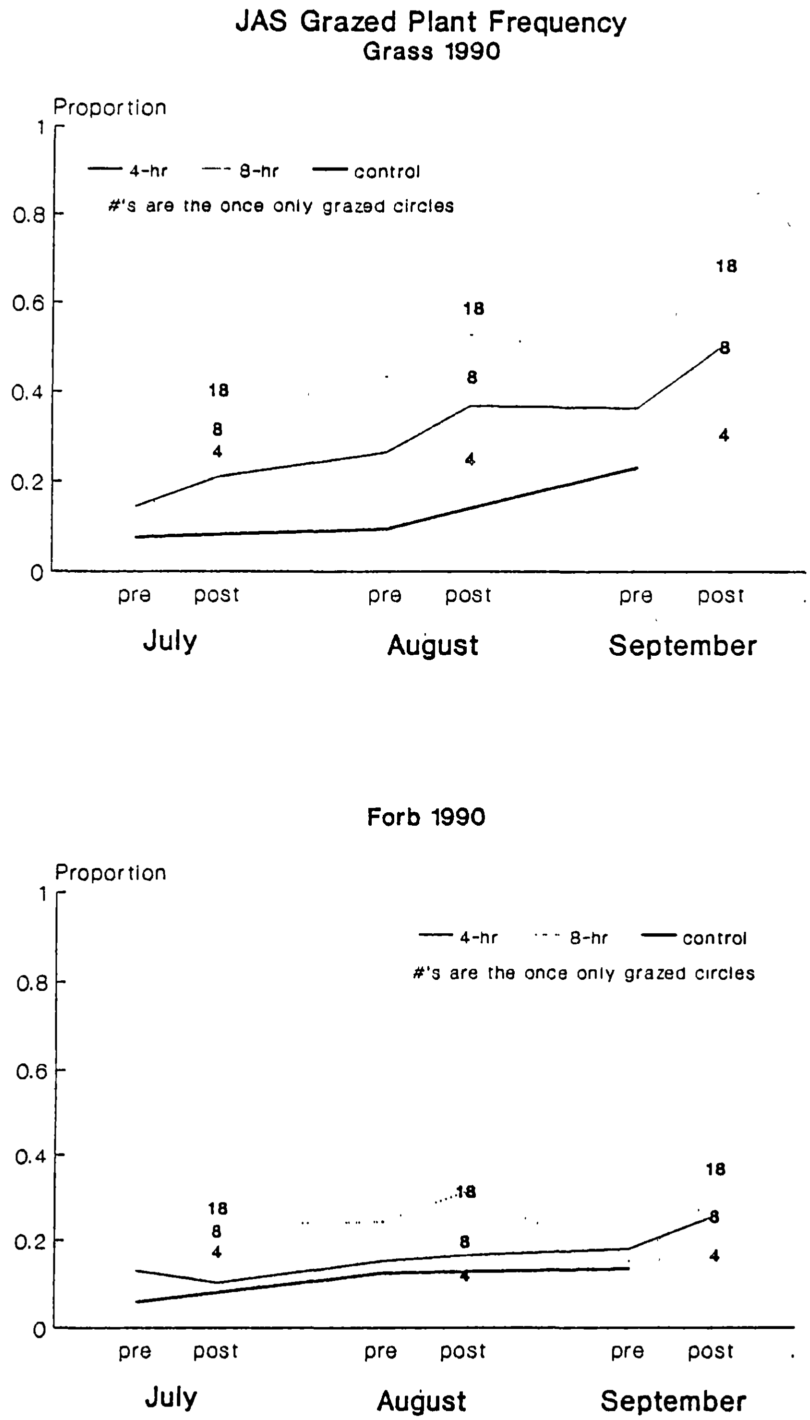

Fig. 11. 1990 grass (a) and forb (b) grazed plant frequency on the repeatedly grazed circles.

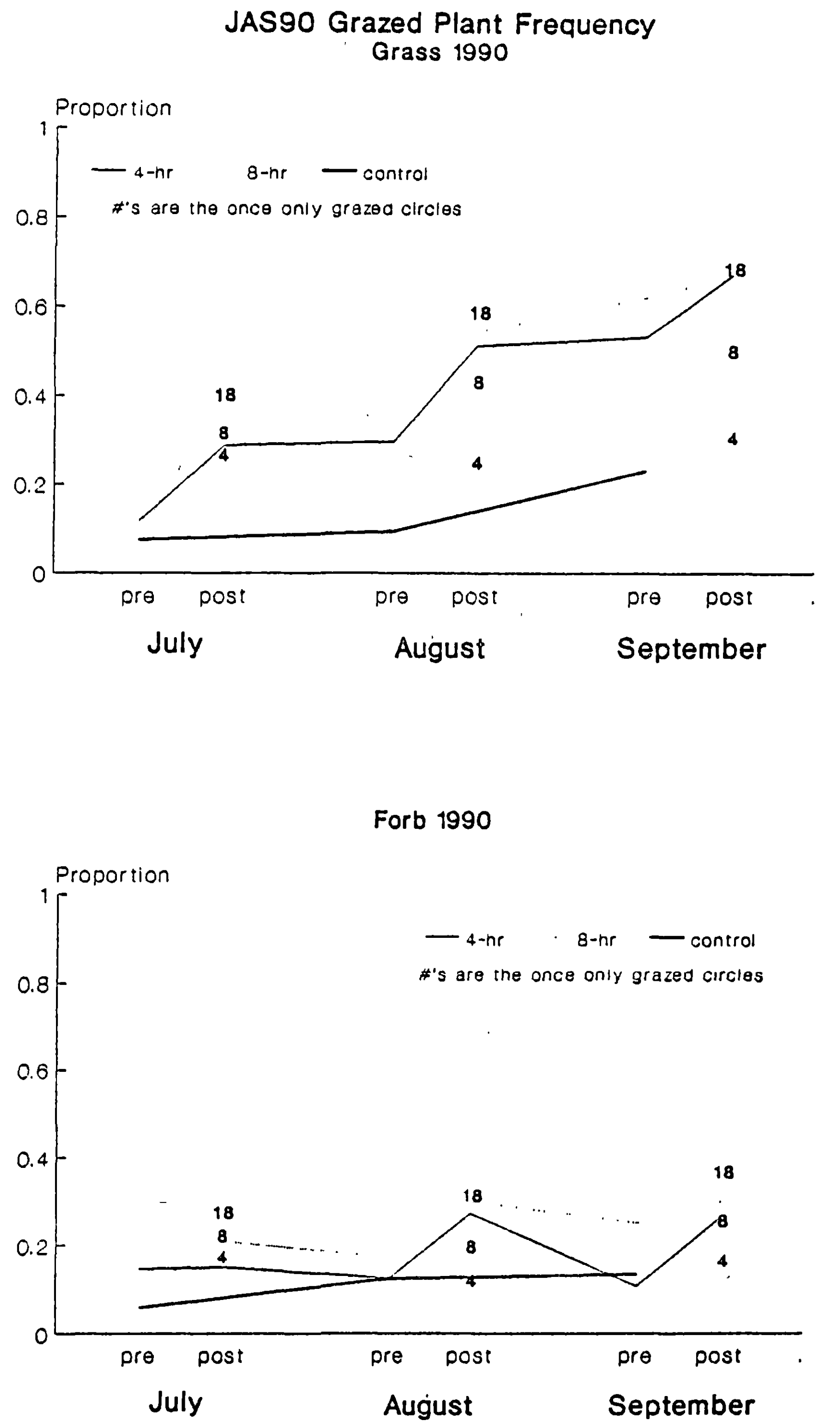

Fig. 12. 1990 grass (a) and forb (b) grazed plant frequency on the JAS90 circles.

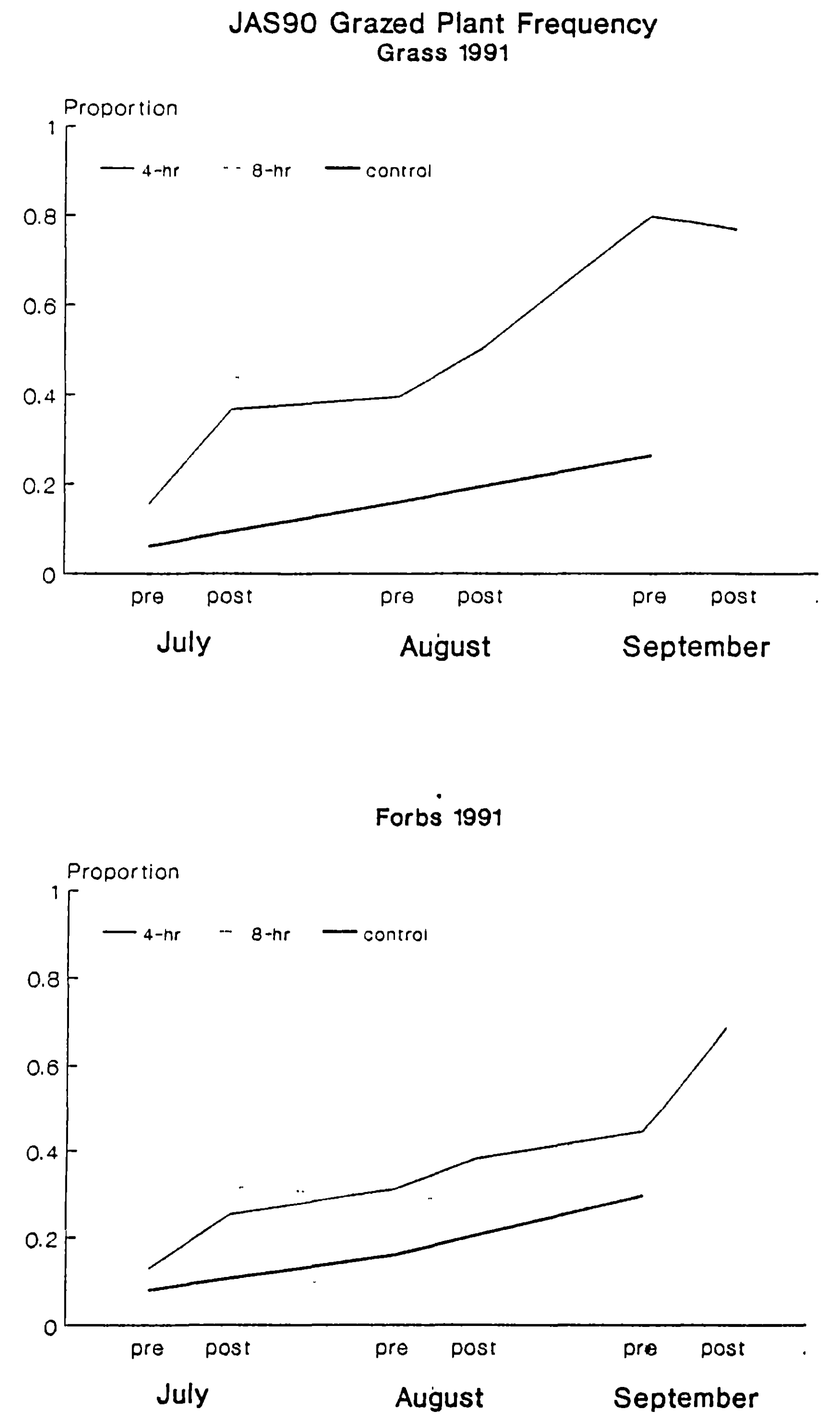

Fig. 13. 1991 grass (a) and forb (b) grazed plant frequency on the JAS90 circles.

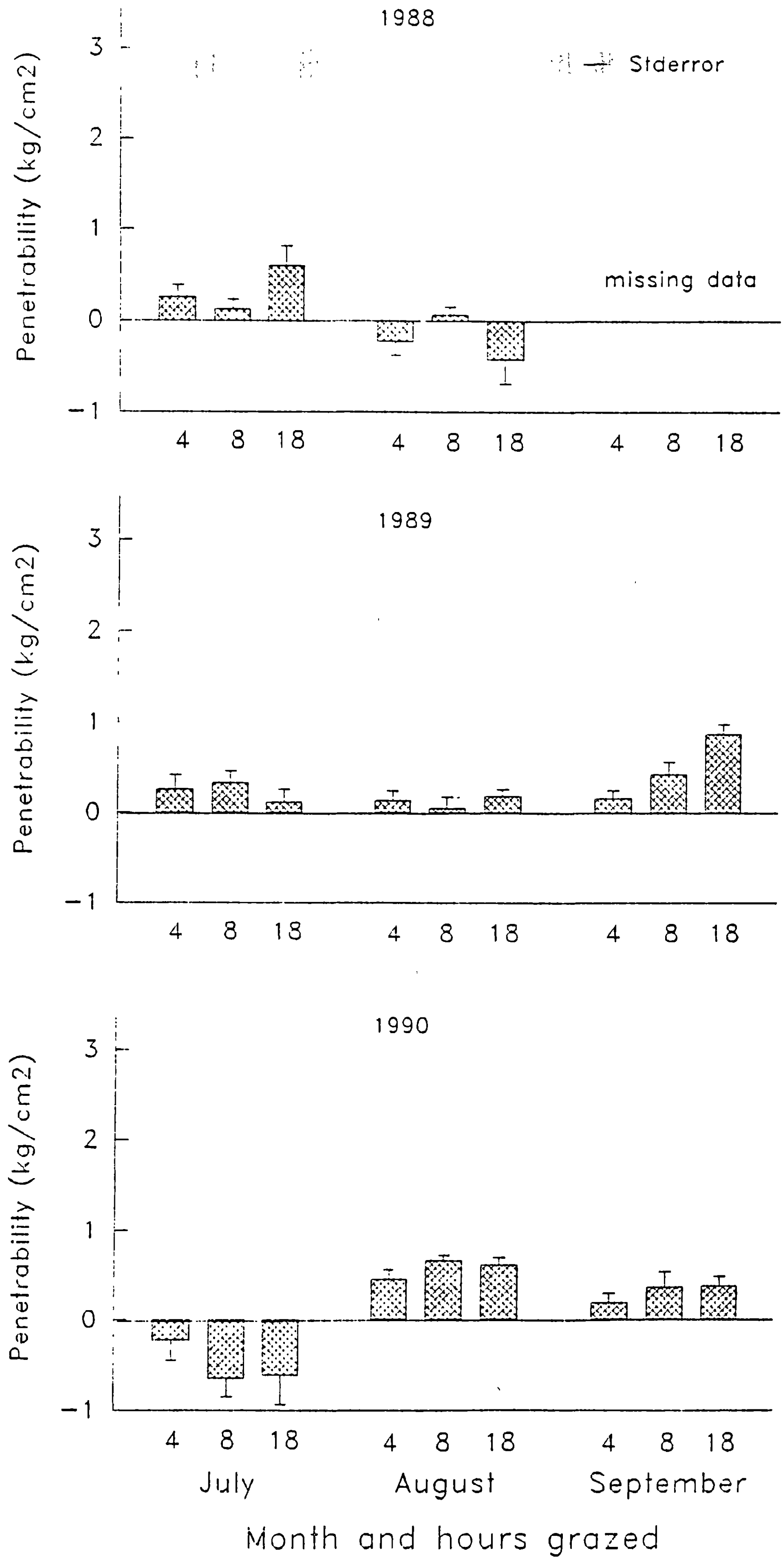

Fig. 14. Immediate change in soil surface penetration resistence in a) 1988, b) 1989, and c) 1990.

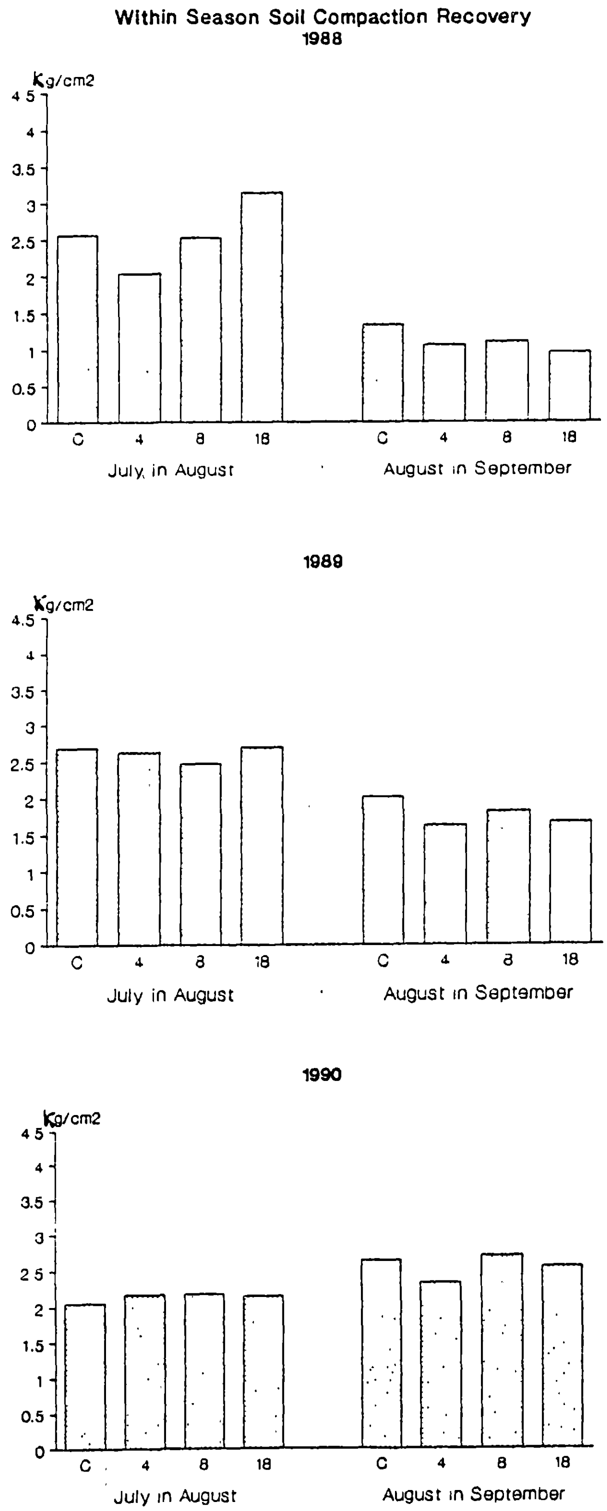

Fig. 15. Soil penetration resistence one month after grazing in a) 1988, b) 1989, and c) 1990.

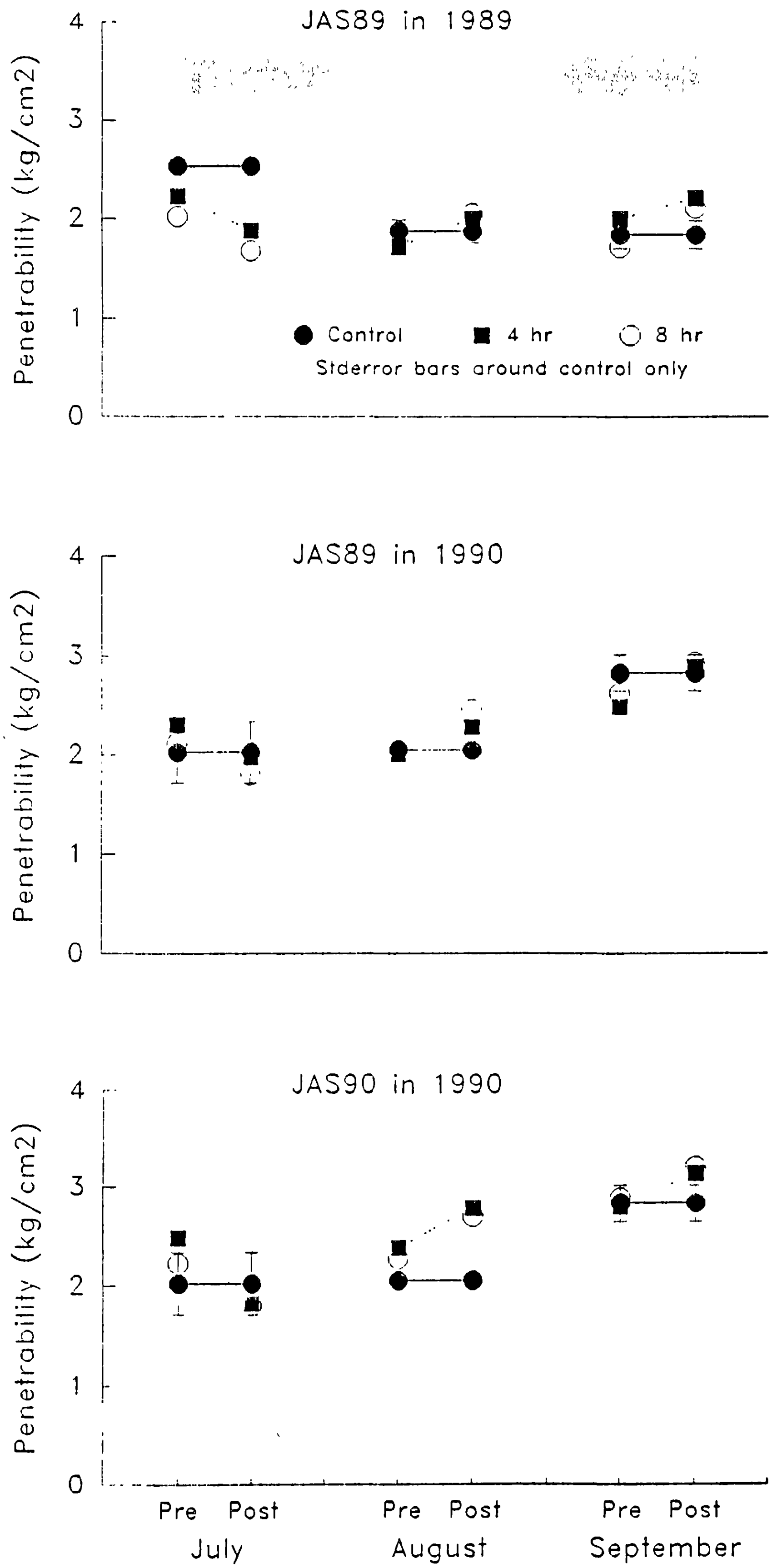

Fig. 16. Soil surface pentration resistence through the summer on a) JAS89 in 1989, b) JAS89 in 1990, and c) JAS90 in 1990.

the ungrazed circles. Soil penetration resistance data on the JAS90 circles grazed in 1991 are not yet summarized.

Immediate changes in soil compaction did not correlate with percent soil, litter and rock cover. This may be partially a result of methodology, since the readings were taken only between plant bases and not on rock surfaces. There was one exception. The change from pregrazing July to postgrazing September on the JAS circles in 1990 increased with increase in bare soil. The partial regression coefficient indicates that bare soil would have to increase 100% to see a corresponding increase in penetration resistance of 3 kg/cm_2.

2. Short-term Impact:

By remeasuring circles one year after they were grazed, we assessed the impact of one season's grazing on the meadow soils and vegetation the following growing season. The circles grazed in 1988 were remeasured in August 1989, those grazed in 1989 were remeasured in mid July 1990, regrazed that summer and measured in July 1991. The JAS90 circles were regrazed in 1991 and will be measured in July 1992.

We needed to account for differences among circles before grazing and to adjust for different time periods over which the change from initial to one-year-later observations were made. To make these adjustments we calculated a relative index of change, as described in the methods section.

a) Cover:

Since the September 1988 pregrazing data are missing, we could not calculate the relative change index for that month. Vegetal cover decreased with 18-hours grazing in August, with a corresponding increase in bare soil (Fig. 17). Rock cover also increased on all August circles, but because the same pattern occurred on the ungrazed controls increased rock cover was not a function of horse grazing (Fig. 17). No other changes in cover were detected. We have not yet done power tests to determine the sensitivity of the data.

The relative changes in cover from pregrazing 1989 to 1990 are shown in figure 18. It appears that all durations of grazing in August and September reduced vegetal cover (Fig. 18). The vegetal cover loss appears

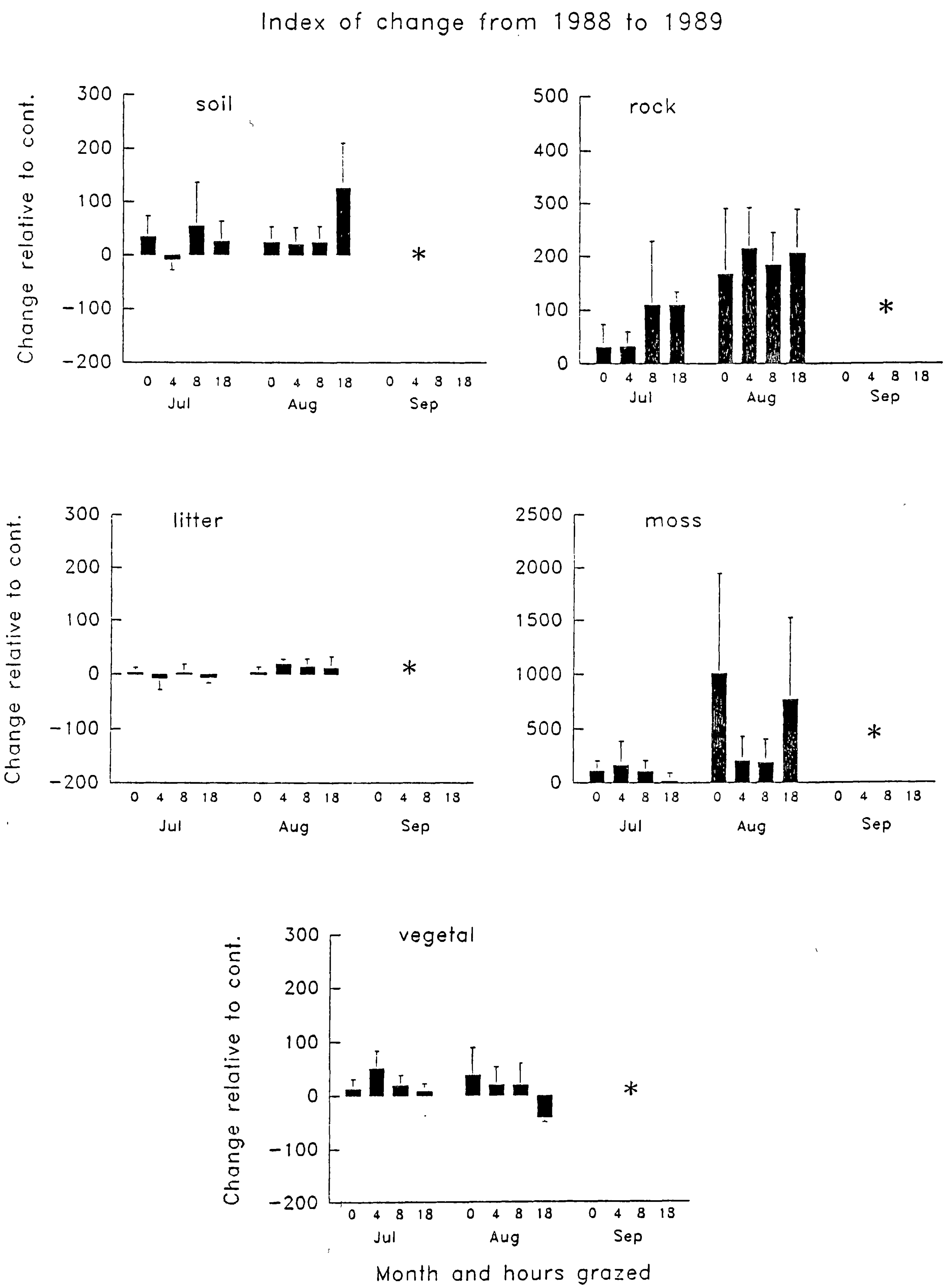

Fig. 17. Relative change in bare soil, rock, litter, moss, and vegetal ground cover from 1988 to 1989 (means and stderr).

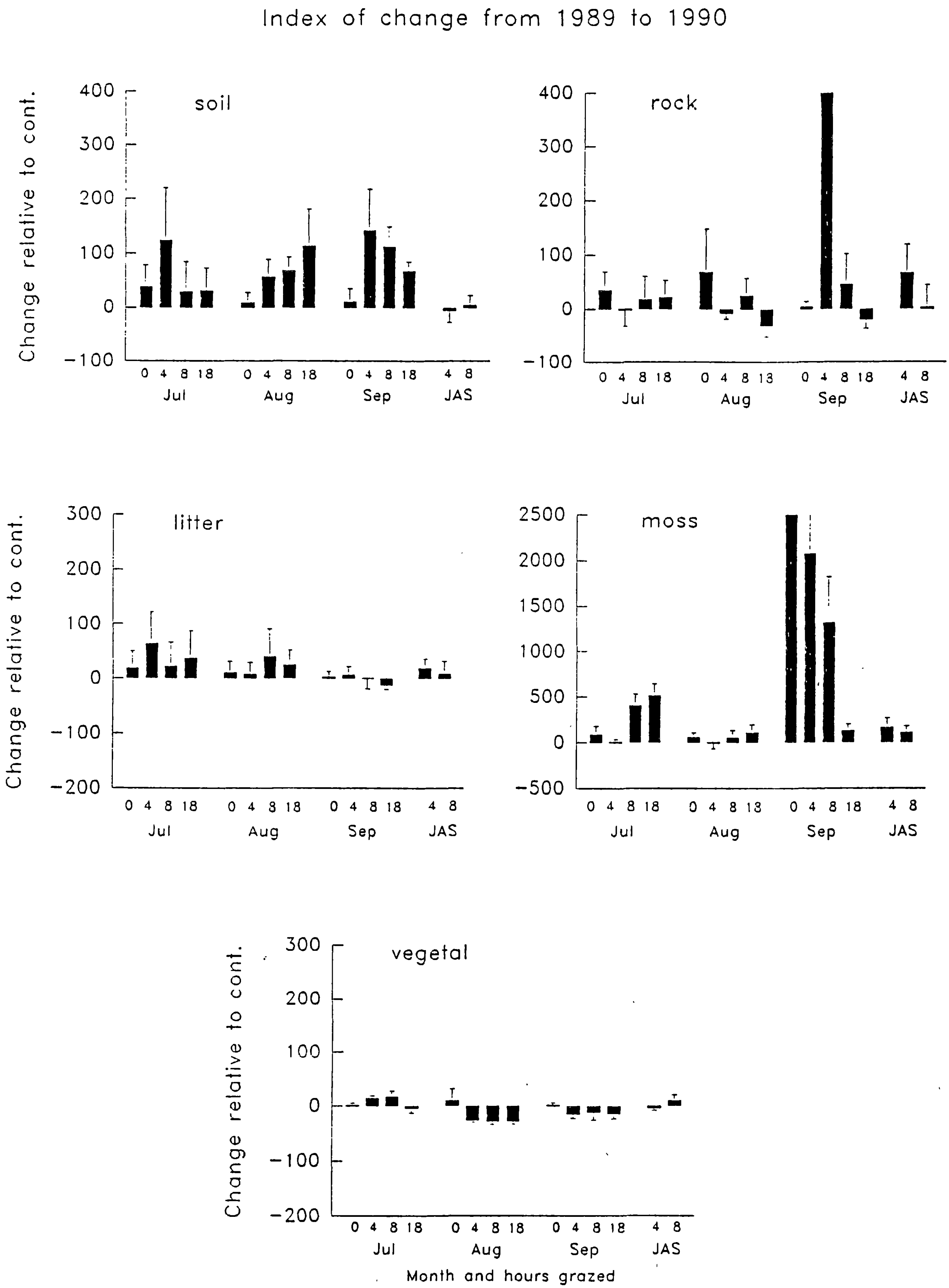

Fig. 18. Relative change in bare soil, rock, litter, moss, and vegetal ground cover from 1989 to 1990 (means and stderr).

to correspond with an increase in bare soil (Fig. 18). September's circles had a significant increase in moss as compared to the others months. The increase appears to be less with increasing grazing duration (Fig. 18). There were no other consistent patterns of ground cover change. The repeatedly grazed circles (Fig. 18, JAS) do not appear any different from the other grazing treatments.

After two years of grazing under the same treatments, there is no pattern of change in cover (Fig. 19). The only trend may be towards an increase in bare soil (Fig. 19), however no single other cover type appears to have a corresponding decrease. The repeatedly grazed circles (JAS) are not different from the other grazing durations.

b) Grass and Forb Stem Counts:

The relative changes in stem counts from one year to the next have been summarized, but not yet statistically analyzed. However, given the large standard errors (Fig. 20) on some grazing treatments, statistical tests by not be very powerful. Power curves will be calculated for these data to incorporate into journal publications.

The most noticeable change in stem counts from 1988 to 1989 is a reduction of grass and forb stem numbers with 18 hours of grazing in August (Fig. 20a). This corresponds with the reduced vegetal cover and increased bare soil found under the same grazing treatment (Fig. 17). There also appears to be a reduction in grass stems with eight hours of grazing in both July and August, with a corresponding increase in forb numbers.

On the meadow grazed in 1989, all grazed circles, except 4- and 8-hours in July, decreased grass stem numbers in 1990 (Fig. 20b). Forbs increased with 8- and 18-hours grazing in July, stayed constant with August grazing, and decreased with grazing in September. These changes also correspond to reductions in vegetal and increases in bare soil cover (Fig. 18). The repeatedly grazed circles appeared to reduce grass stem counts (Fig. 20b, JAS), and with 8-hours increased forb stem numbers.

After two years of grazing, the July 8- and 18-hour circles had reduced grass (Fig. 20c) and increased forb stem counts. August and September grazing had little influence on forb numbers. However, 8-hours

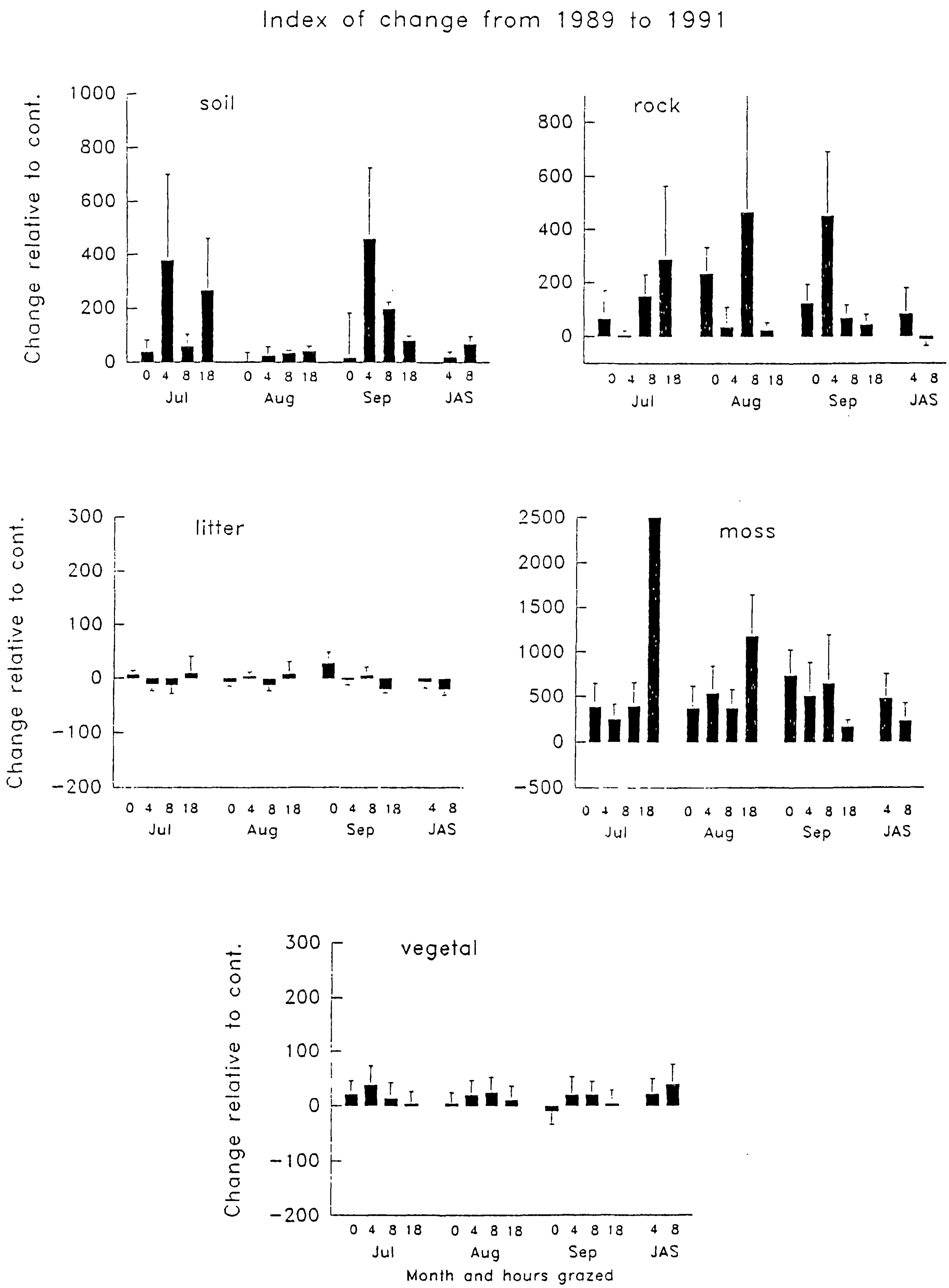

Fig. 19. Relative change in bare soil, rock, litter, moss, and vegetal ground cover from 1989 to 1991 (means and stderr).

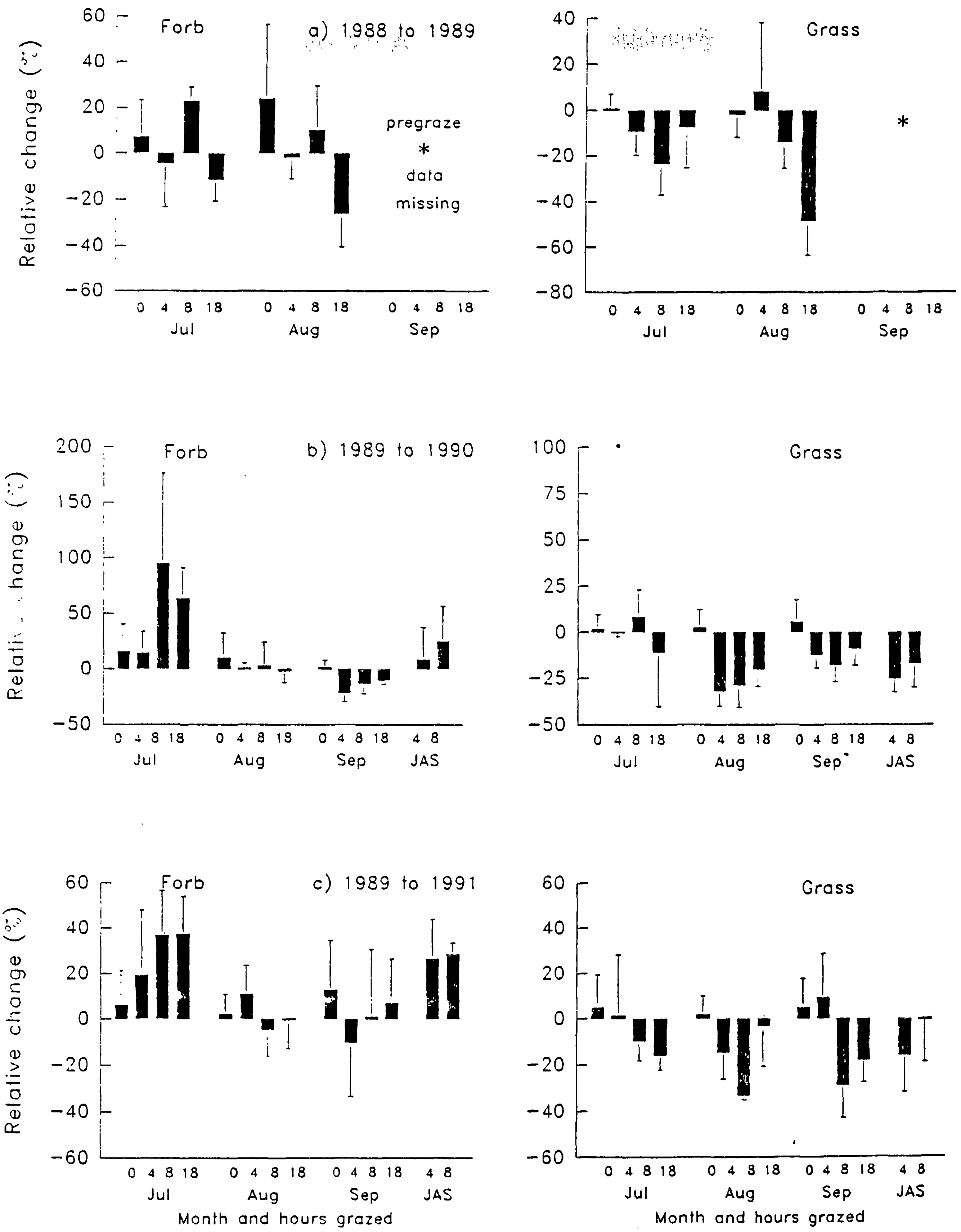

Fig. 20. Relative change in forb and grass stem counts per $10cm^2$ from a) 1988 to 1989, b) 1989 to 1990, and c) 1989 to 1991.

in August and 8- and 18-hours in September appeared to reduce grass stem counts. Repeated grazing (JAS) appeared to increase forb numbers. The grass stem counts were reduced by repeated 4-hours, but not 8-hours.

c) Plant Height Class Distribution:

The relative changes from 1988 to 1989 for each height class by month and duration grazed in 1988 are presented in Table 5. The erratic pattern, high variability, and the high values for the ungrazed circles, which should be close to 1.0, make the validity of this index for these data questionable. Unless a better index or method of analysis is found, we will have to look at the absolute change from 1988 to 1989 on a per month basis (calculated as 1989-1988, such that a negative value implies decrease from 1988 to 1989). Yet, with these data also, there is high variation (standard error) among circles grazed for the same duration (e.g. Fig. 21, height 3), and no strong pattern of change by duration or month grazed (Fig. 21, 22). There may be some evidence of an incremental reduction in grasses 4-12 cm tall with increasing grazing duration in August (Fig. 21, height 3). Our remaining option is to compare height class distributions among durations as measured one year later. However, this does not account for pregrazing differences.

The relative changes of height classes from 1989 to 1990 also have high standard error values, show no pattern, and the controls' values are greater than or close the grazed circles' changes (Table 6). This reinforces the questionable validity of this relative change index. However, there may be a pattern of change if we look at the absolute change from 1989 to 1990 (Fig. 23, 24). The circles grazed in July 1989 had less of a reduction in the percent of grasses in height classes 1 and 3 (Fig. 23), and less of an increase in height 5, and height 4 with 18-hours grazing, than the ungrazed circles. The forbs did not appear affected by July grazing (Fig. 24). August grazing had less influence on the grasses except, perhaps a shift from grasses taller than 24 cm (Fig. 23, height 5) to between 12-24 cm (height 4). The forbs, however, did appear influenced by August grazing. There was less of a decrease in height 2 forbs (Fig. 24), and less of an increase in heights 4 and 5 forbs on the grazed than the ungrazed circles. Four- and 8-hour grazing in September appeared to decrease the amount of short

Table 5. Height-class relative change index from 1988 to 1989 by plant type, month, and duration grazed (mean±stderr).

Spp	Mnth	Hrs	Ht-class 1	Ht-class 2	Ht-class 3	Ht-class 4	Ht-class 5
Forb	Jul	0	57.6±42.4	16.2±21.4	0.6±4.5	3779.7±3471.5	211.2±93.5
		4	-20.7±35.6	62.6±36.9	4.8±23.8	343.2±162.3	305.1±0.0
		8	59.9±28.9	68.0±24.7	20.4±22.1	321.0±173.5	1345.3±1298.0
		18	319.8±305.4	22.1±35.4	7.1±14.6	3477.0±2215.3	114.1±110.3
	Aug	0	1080.9±1061.0	20.0±28.8	2.5±8.9	147.9±164.2	0.0±0.0
		4	-50.0±19.5	-0.2±46.9	26.0±27.8	853.1±914.3	584.8±364.8
		8	144.9±65.8	-26.5±7.8	20.1±29.6	17.3±74.5	607.9±351.0
		18	20.2±72.0	149.9±117.7	2.1±31.4	-49.9±23.2	-0.1±0.1
Grass	Jul	0	7137.1±6854.4	66.9±61.1	2.6±9.2	211.6±210.0	659.6±432.5
		4	14058.1±5458.8	254.4±269.3	-1.9±14.7	682.5±683.5	4318.0±3408.8
		8	14072.0±7863.9	23.0±62.2	-4.9±18.1	74.5±63.8	7300.0±4181.4
		18	4003.1±3277.6	975.3±738.4	34.1±45.7	1522.3±1348.6	528.1±282.5
	Aug	0	7175.0±3654.3	34.0±38.1	2.8±9.9	39.7±37.7	577.3±350.4
		4	1666.1±1349.7	-3.1±42.7	-3.6±23.3	116.2±69.6	12201.1±11171.7
		8	292.1±139.3	84.4±114.2	-22.8±5.7	89.3±21.0	5999.8±5607.5
		18	1739.3±1333.5	-61.8±13.0	-37.0±10.7	818.8±781.0	12229.3±11163.5

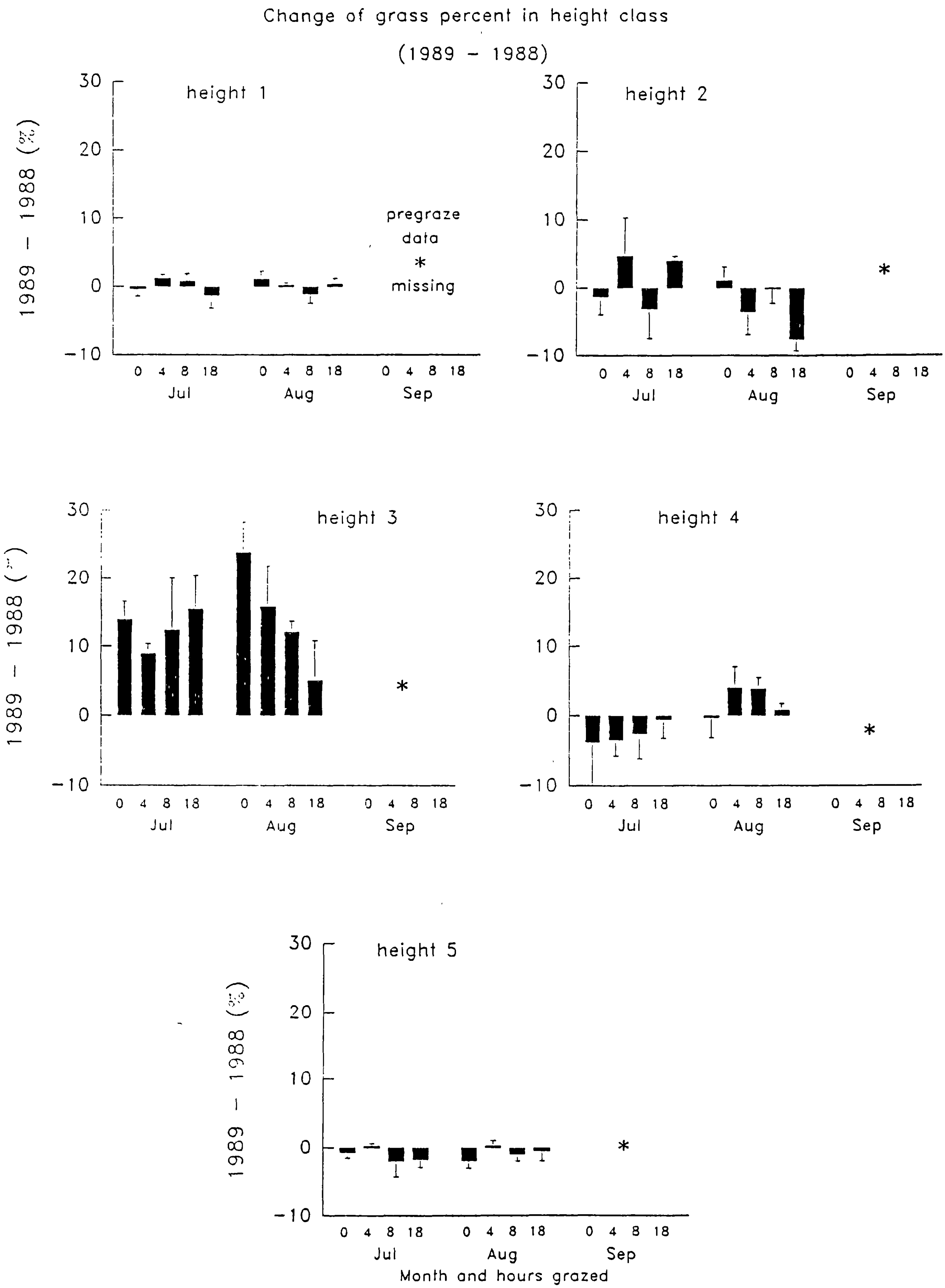

Fig. 21. Absolute change in percent of grasses in each height class from 1988 to 1989. Comparisons can only by made among durations within a month.

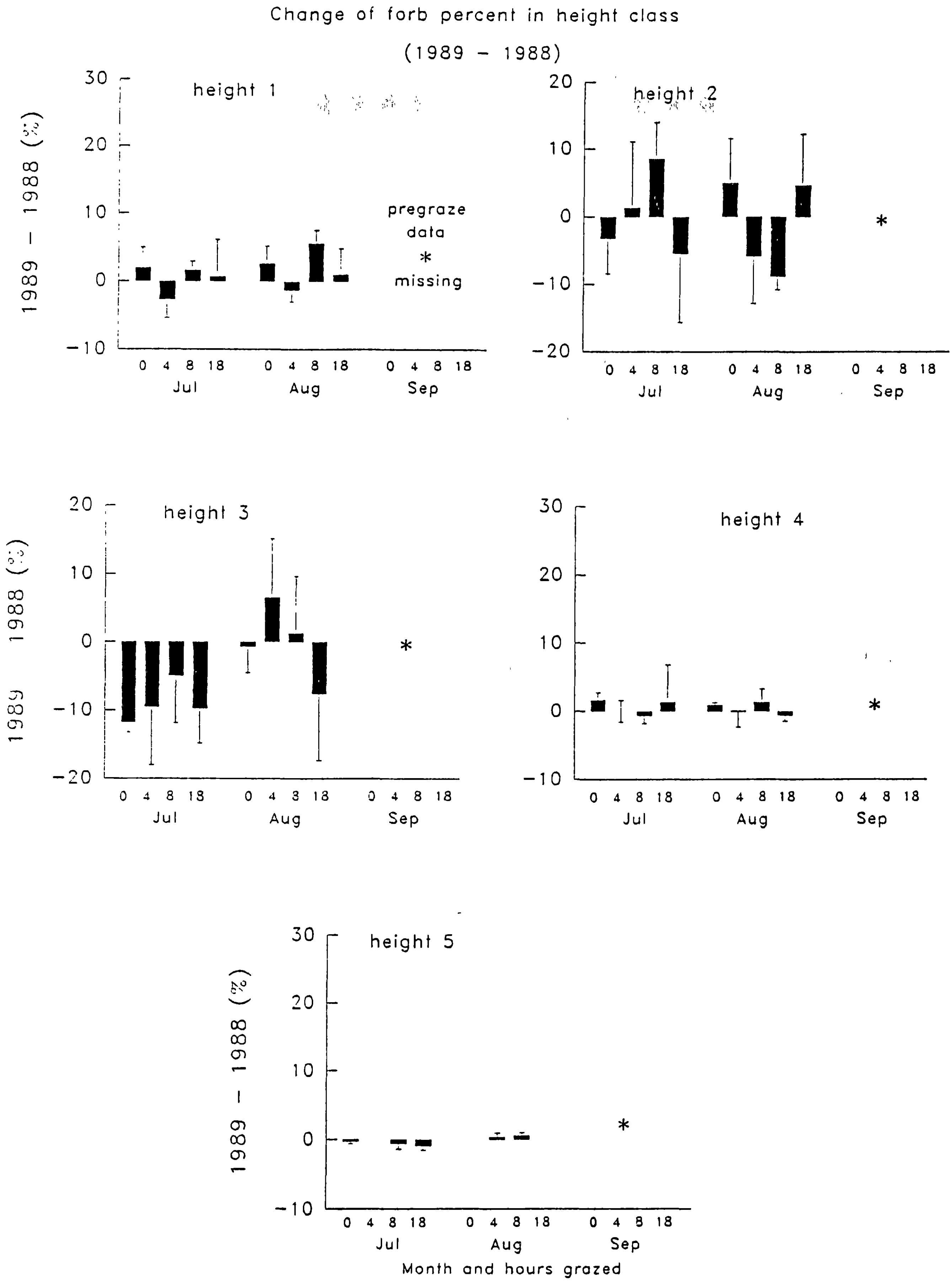

Fig. 22. Absolute change in percent of forbs in each height class from 1988 to 1989. Comparisons can only by made among durations within a month.

Table 6. Height class relative change index from 1989 to 1990 by plant type, month, and duration grazed (mean±stderr).

Spp	Mnth	Hrs	Ht-class 1	Ht-class 2	Ht-class 3	Ht-class 4	Ht-class 5
Forb	Jul	0	1415.0±780.3	83.5±71.7	8.9±19.94	14.5±157.93	3488.1±2181.1
		4	1202.0±370.3	124.5±28.1	20.3±9.4	-28.1±24.1	5721.9±1164.4
		8	2829.0±955.2	109.0±59.7	5.7±9.4	37.1±35.5	5049.6±4614.7
		18	3081.7±1893.2	117.6±28.6	17.9±17.6	892.2±593.6	1249.3±1105.5
	Aug	0	633.3±598.2	100.2±115.4	1.6±7.2	276.5±262.4	106.8±88.9
		4	-27.6±33.8	297.6±122.9	16.9±12.5	352.5±430.5	-23.6±55.4
		8	87.4±61.3	199.2±39.5	40.0±19.3	118.9±170.3	-68.5±15.6
		18	-58.9±19.7	338.2±136.1	7.1±19.1	-39.4±19.0	-53.9±26.8
	Sep	0	99.9±79.0	24.2±30.2	5.0±12.3	1070.5±1079.5	0.0±0.3
		4	21.5±30.9	68.0±25.5	20.7±20.8	829.4±514.3	1604.9±1236.4
		8	43.5±60.6	97.8±52.5	-13.9±12.7	2127.2±743.8	1253.9±723.8
		18	17.1±32.5	92.9±57.3	8.0±13.5	919.1±860.2	929.5±960.8
Grass	Jul	0	1119.5±644.8	12.5±18.9	6.1±12.9	21.4±25.4	244.5±216.3
		4	8273.7±7421.1	129.6±49.2	34.2±31.3	144.1±80.8	56.4±93.1
		8	1123.3±642.5	182.0±115.6	34.1±25.0	47.8±25.0	114.7±164.4
		18	1307.9±551.5	112.0±91.3	36.1±25.9	10.1±50.4	8.7±63.2
	Aug	0	4952.4±4679.7	226.2±186.8	1.5±7.1	29.1±32.5	49.9±50.4
		4	171.7±160.2	144.8±60.9	-5.3±13.5	6.1±13.2	2107.7±720.3
		8	-69.4±9.2	78.5±57.3	12.6±18.1	183.2±92.9	1039.8±534.1
		18	107.9±175.6	444.0±167.4	8.8±11.1	63.9±33.5	524.6±499.2
	Sep	0	117.9±106.0	38.8±46.9	20.2±27.9	91.6±77.7	264.0±196.1
		4	12.1±35.5	-6.4±15.0	39.9±21.3	2973.1±2879.9	1120.3±397.9
		8	175.5±175.1	-20.4±10.5	15.6±14.6	145.4±78.7	442.7±308.1
		18	-61.8±9.3	-0.9±5.0	48.4±20.8	6.7±17.5	190.4±200.9

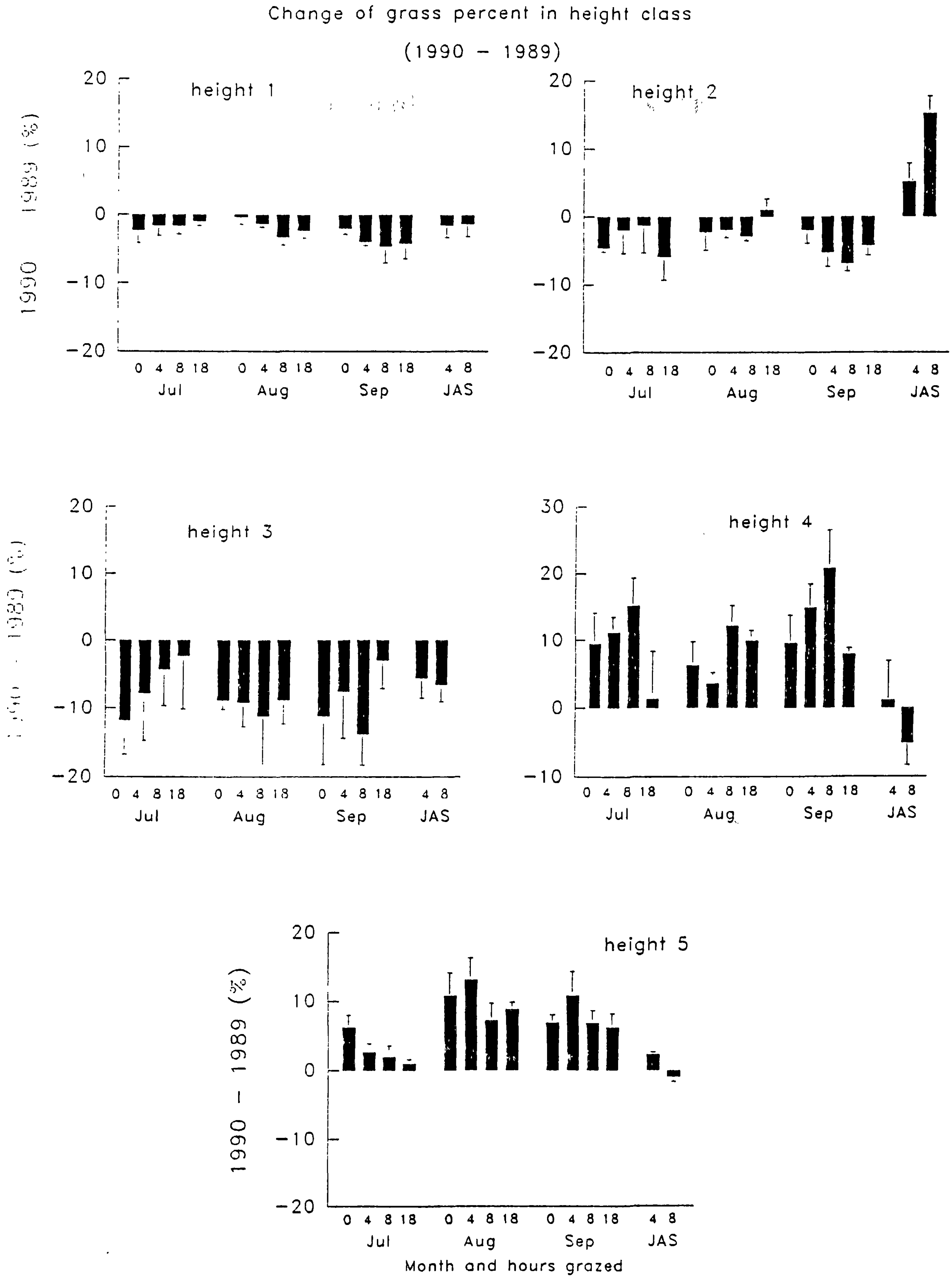

Fig. 23. Absolute change in percent of grasses in each height class from 1989 to 1990. Comparisons can only by made among durations within a month. JAS can only be compared to July 0-hours.

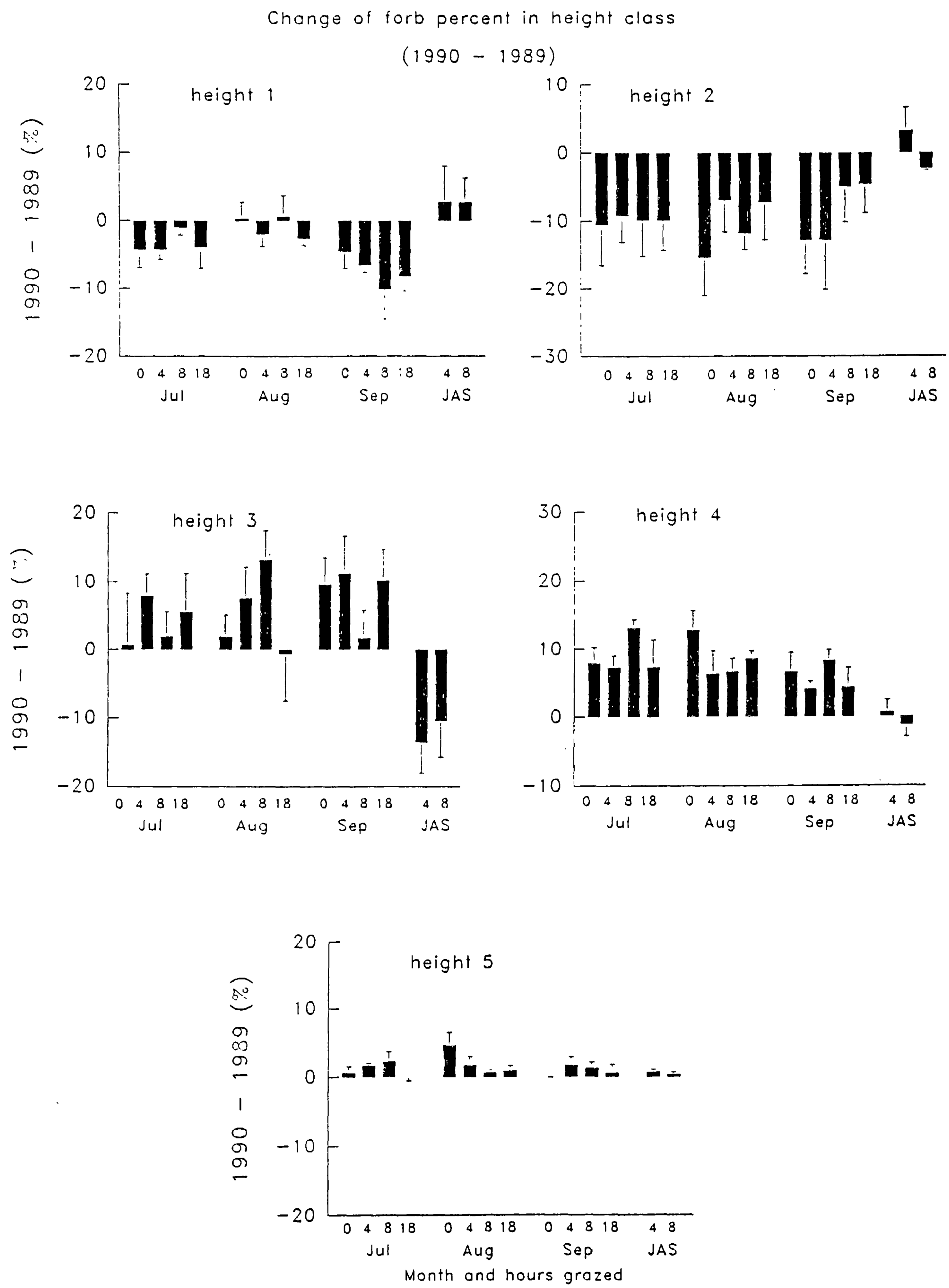

Fig. 24. Absolute change in percent of forbs in each height class from 1989 to 1990. Comparisons can only by made among durations within a month. JAS can only be compared to July 0-hours.

grasses (Fig. 23) and increase the percent of grasses between 12-24 cm (height 4) as compared to the ungrazed circles. The pattern on the forbs is not clear (Fig. 24). The repeatedly grazed circles (JAS) can only be compared to the July circles, since they were measured in July 1989 and again in July 1990. Repeated grazing appeared to reduce the percent of grasses greater than 12 cm (heights 4 and 5, Fig. 23) and increase the percent of grasses less than 4 cm (height 1 and 2). The impact on forbs was similar, with a reduction of plants greater than 4 cm (Fig. 24) and increase in plants less than 4 cm.

We can evaluate the impact of two seasons grazing on plant heights by looking at the change from pregrazing 1989 to pregrazing 1991. The problems with the relative change index (Table 7) are the same as with this index calculated for 1988 to 1989, and 1989 to 1990. For example, the relative change of forbs in height class 4 on the ungrazed circles is much greater than any of the grazed circles , yet, this index should calculate the change over time relative to the control (ungrazed circle), thus the controls' values should be close to 1.0. Therefore we looked at the absolute change in percent of plants in each height class from pregrazing 1989 to July 1991. Grazing duration comparisons can only be made within a month to avoid confounding month grazed with the time of summer the circles were measured in 1989. There is not a definitive pattern, except, perhaps the circles grazed 18-hours in July and all grazed circles in August and September had fewer grasses taller than 12 cm (height 3) than the ungrazed circles (Fig. 25). All circles grazed in September appeared to have fewer forbs taller than 12 cm than the controls (Fig. 26). Repeated grazing through the summer (JAS) did not appear to affect forb height classes (Fig. 26), however, these circles did appear to have fewer grasses taller than 12 cm than the ungrazed circles (Fig. 25).

d) Grazed Plant Frequency:

Grazed plant frequency the summer after horse grazing and before additional horse grazing indicates whether our treatments influenced elk grazing the following season. Elk grazing was not influenced by the previous year's duration or month of grazing in any year. In August 1989, on the area grazed in 1988 elk preferred grasses (13.7% grazed) over forbs (8.6% grazed). On the 1989 grazed area, measured in July 1990, elk preferred forbs (8.4%) over grasses (6.7%). One year later (July 1991)

Table 7. Height-class relative change index from 1989 to 1991 by plant type, month, and duration grazed (mean±stderr).

Spp	Mnth	Hrs	Ht-class 1	Ht-class 2	Ht-class 3	Ht-class 4	Ht-class 5
Forb	Jul	0	55.1±50.1	73.9±61.3	23.6±30.5	1223.4±1236.0	6470.7±4161.0
		4	52.9±32.3	62.8±56.4	24.6±13.6	75.3±80.5	10986.1±5381.0
		8	268.0±230.6	114.0±86.7	21.1±4.3	66.8±58.1	4519.6±4272.9
		18	140.1±128.1	65.6±34.9	33.5±8.5	573.6±424.9	480.3±82.5
	Aug	0	710.3±693.4	32.4±42.8	3.6±10.8	119.8±94.8	456.3±480.4
		4	4.9±37.3	55.8±23.6	6.1±6.3	103.1±102.7	653.3±249.2
		8	155.4±92.4	61.9±27.6	4.7±8.9	114.1±102.1	938.6±689.3
		18	23.4±48.1	192.7±102.2	-5.3±25.6	88.6±103.5	475.2±474.4
	Sep	0	11.2±21.6	10.4±21.3	9.2±17.1	359.4±380.5	6845.6±4225.2
		4	138.5±140.0	66.6±32.6	29.7±29.1	75.5±106.2	9100.7±3540.5
		8	9.9±30.2	34.5±34.0	12.7±28.4	518.4±267.5	4765.9±2413.7
		18	45.5±25.9	106.1±53.1	3.3±17.5	305.7±227.8	4607.6±2508.4
Grass	Jul	0	757.4±747.0	19.2±28.2	4.0±11.3	16.7±24.9	0.0±0.0
		4	3204.5±2051.1	37.6±71.5	-20.1±22.2	106.6±126.5	49.8±49.8
		8	971.4±935.0	1395.2±1438.7	19.5±18.4	-0.8±45.7	1267.5±907.6
		18	559.8±555.4	544.0±593.1	20.9±11.0	-50.2±17.9	0.0±0.0
	Aug	0	293.4±209.6	69.3±83.5	8.2±15.0	222.4±123.6	211.4±234.5
		4	320.4±336.6	357.7±211.8	-2.8±8.8	-2.4±50.2	6872.0±3715.0
		8	-21.4±35.7	262.7±136.6	-26.1±10.1	50.8±84.5	670.9±244.1
		18	187.6±221.8	17.6±35.7	8.1±16.2	73.9±38.0	951.5±697.9
	Sep	0	18.3±23.0	13.5±24.0	11.2±17.6	104.4±80.8	7010.0±3968.7
		4	-1.1±37.3	99.5±88.7	21.4±17.8	171.0±191.5	2608.2±2039.5
		8	-34.4±17.4	-9.5±6.5	-3.5±17.1	-8.9±34.9	6683.2±4119.1
		18	37.7±60.6	0.0±26.8	26.1±19.2	-10.3±41.6	2290.8±2150.6

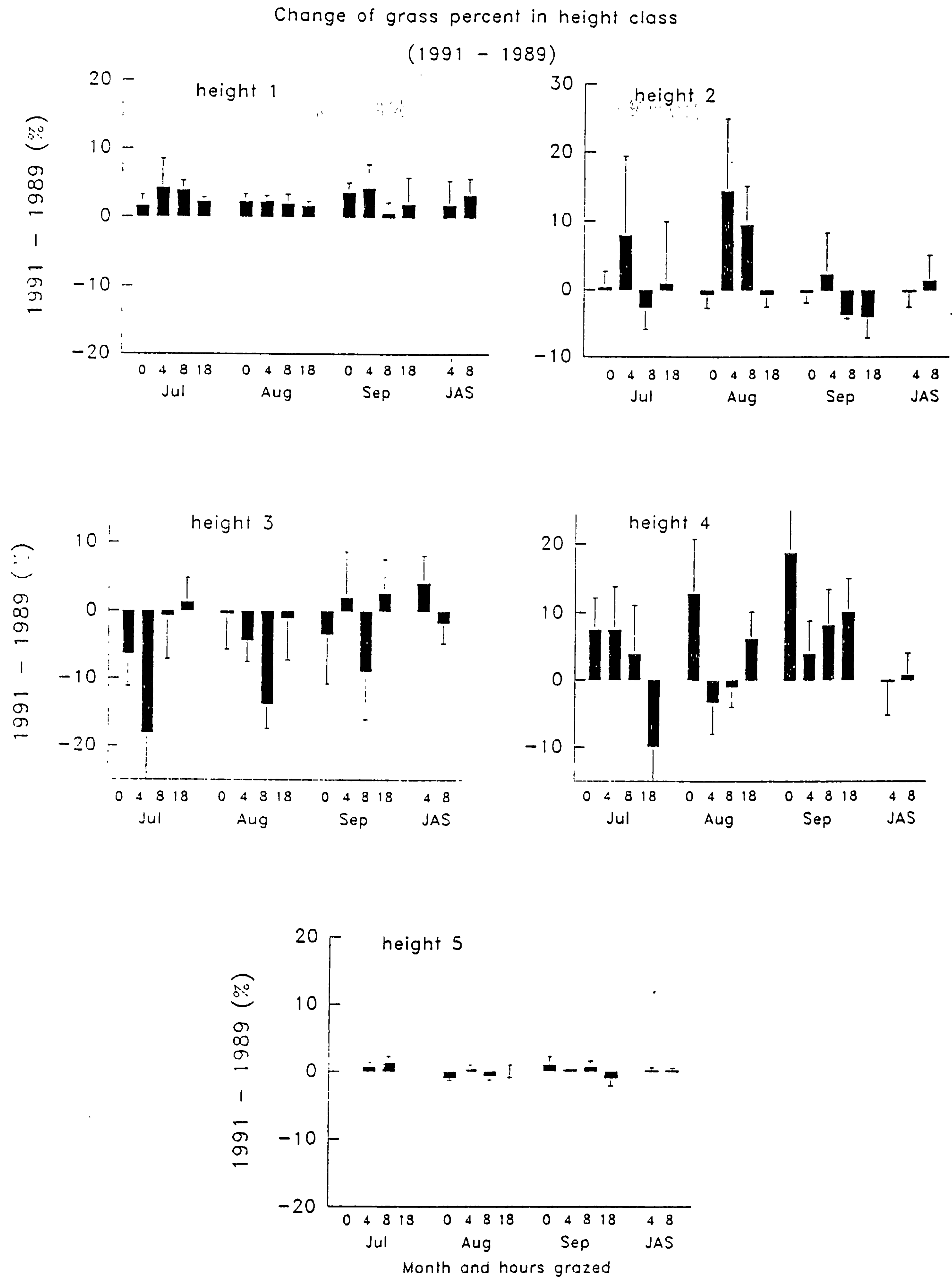

Fig. 25. Absolute change in percent of grasses in each height class from 1989 to 1991. Comparisons can only by made among durations within a month. JAS can only be compared to July 0-hours.

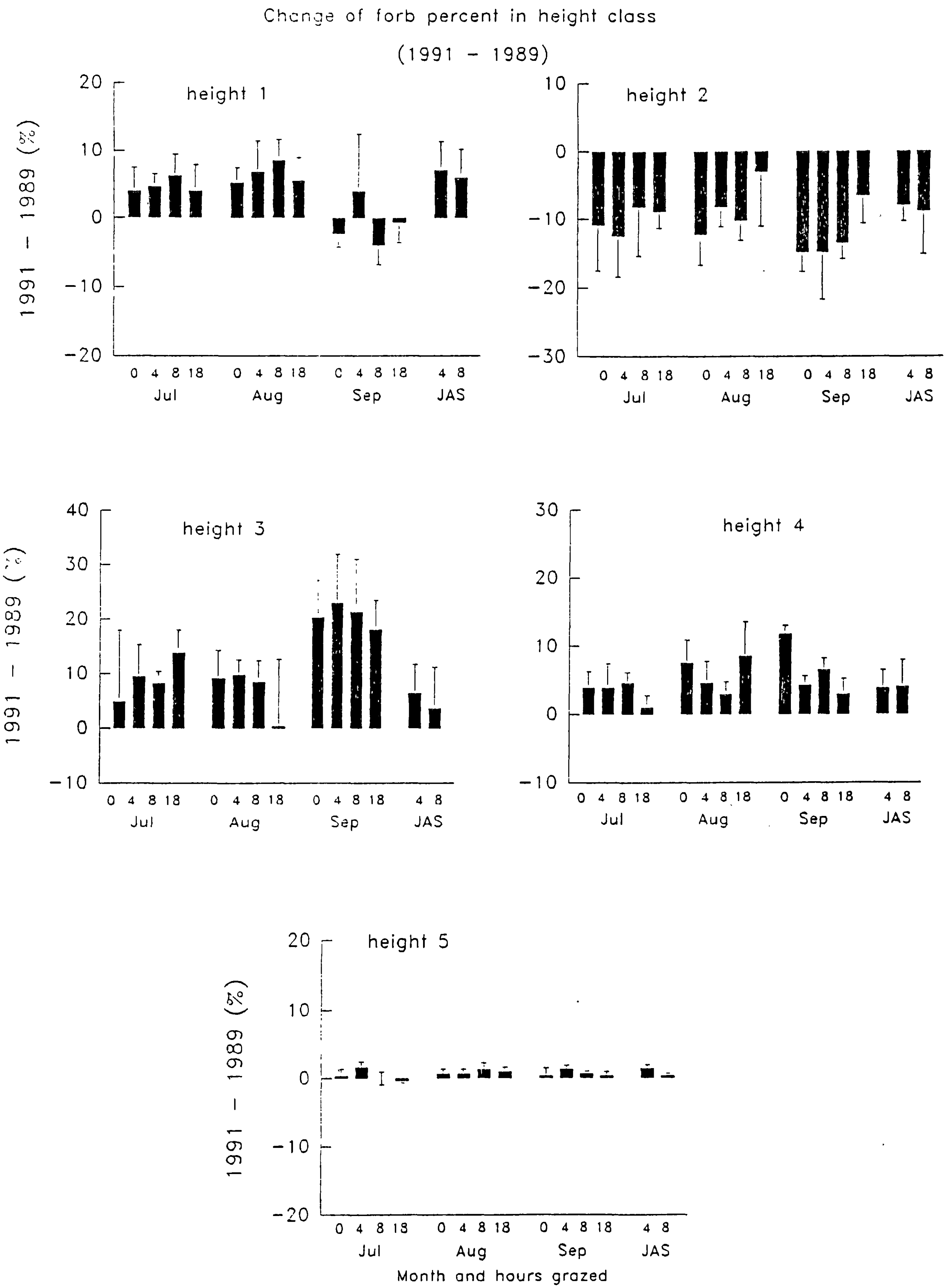

Fig. 26. Absolute change in percent of grasses in each height class from 1989 to 1991. Comparisons can only by made among durations within a month. JAS can only be compared to July 0-hours.

there was no preferential grazing (forbs 6.9%, grasses 7.3%). Therefore, the horse grazing did not influence the selection of grasses over forbs by elk grazing the area. This could occur, however, if horse grazing shifted the relative amounts of grasses and forbs available.

e) Soil Surface Penetration Resistance:

Horse grazing one year could influence soil penetration resistance one year later several ways. We did measure an immediate effect of the animals after grazing. This may carry over to the following year. However, that is improbable, since we could not detect a difference among circles one month after grazing. There could be an indirect effect of the vegetation removal, or ground cover changes, which influence snowpack and freeze thaw effects on soil compaction. Soil penetration measured one year after grazing on the 1988 and 1989 meadows was influenced by rock (6.8 kg/cm^2 decrease for every 100% increase in rock cover), bare soil (3.1 kg/cm^2 decrease for every 100% decrease in soil cover), and litter cover (2.2 kg/cm^2 decrease for every 100% increase in litter cover), rather than hours or month grazed the previous summer. Since grazing did influence vegetal, litter, and bare soil cover on some circles, the one year change in soil penetration resistance could have been due to grazing. The influence of cover on penetration resistance readings may also be a function of the technique used with the penetrometer. If the instrument is nestled under litter, between plants, and around rocks, the readings will be very different than if the penetrometer is placed indiscriminately. Since the pocket ring penetrometer only measures penetration resistance in the soil surface, and appears to be sensitive to current soil surface moisture (see immediate impacts results section), caution should be used in interpreting findings using this instrument.

Horse Behavior:

In 1988 we could not detect differences among durations or months in the percent of picket time spent grazing (68%), resting (35%), or traveling (6%), with one exception. In July the 18-hour horses spent more time traveling than those

picketed for 4- or 8-hours (Fig. 27). Statistical analyses for traveling are difficult because the horses spent little time traveling.

The 8- and 18-hour horses used more grazing stations than the 4-hour horses in all three months (Fig. 28). Since forage availability was low in 1988, we interpret the higher number of grazing stations by the 8- and 18-hour horses as movement to find feed, specifically grasses. The hourly number of grazing stations was relatively consistent over time on the picket and did not correlate to time spent grazing (Fig. 29).

The horses spent more time grazing (85%) and less time resting (14%) and traveling (2%) in 1989 than in 1988 (Fig. 30). Again, analyses of traveling are difficult because of infrequent traveling. We think the horses spent more time grazing and less traveling in 1989 than 1988 because they had become accustomed to the location and picketing, and there was more forage available. The horses grazed less and rested more in September than in July and August. There were no differences among durations.

The number of grazing stations was consistent among durations and months (Fig. 28). In 1989 the forage did not become as limited as in 1988, even for the 18-hour horses. The greater forage availability allowed the horses to find and feed on grasses without having to canvas the entire circle. As in 1988, the hourly number of grazing stations did not correlate with time spent grazing and was consistent over time on the picket (Fig. 31).

If horses rest rather than travel when they are not grazing, then they can be left on a picket with minimal further impact to the meadow. In 1988 grazing correlated moderately (Pcorr=0.56) with resting. In July the correlation between grazing and resting was lower than in August and September (Fig. 32). By August and September the horses were more comfortable with being picketed. We also had the unpicketed herd in closer vicinity to the horses on picket circles, adding a comfort factor for the picketed horses.

The correlation between grazing and resting was higher in 1989 than in 1988 (Pcorr=0.97) and was consistent each month (Fig. 33). This correlation did not change as time on the picket increased. Therefore, horses that are accustomed to being picketed will have minimal impact on an area aside from forage removal.

In both years there was no correlation between the amount of traveling by individual horses and postgrazing soil compaction measurements.

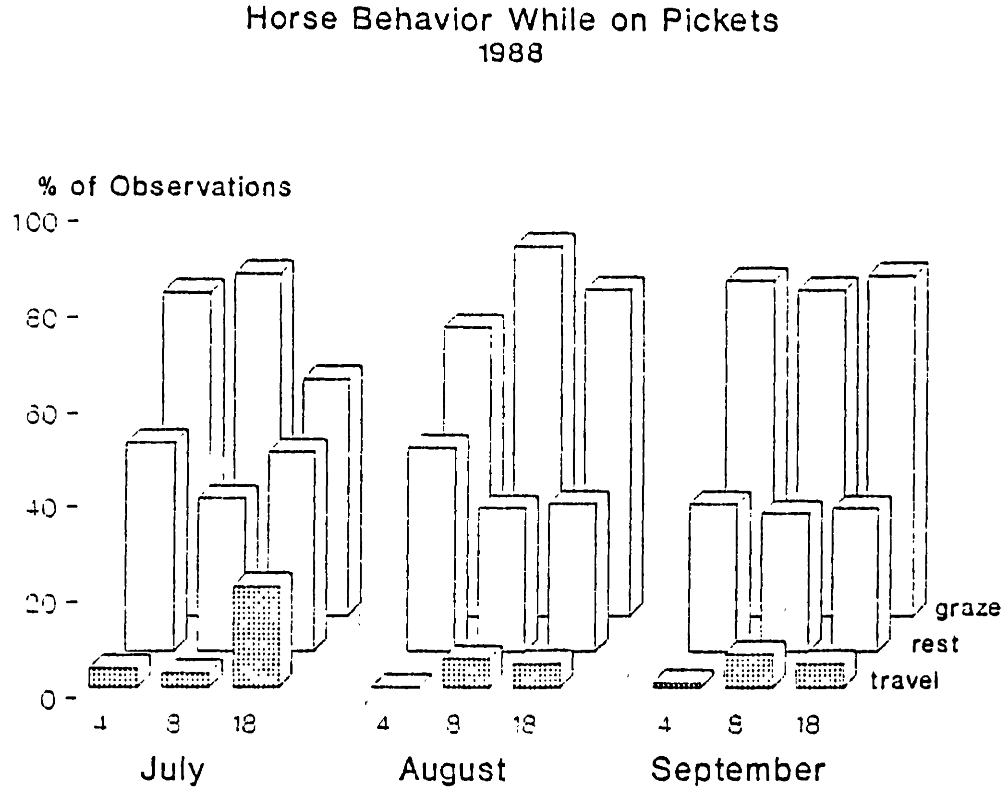

Fig. 27. Percent of picket time spent traveling, resting, or grazing by the horses in 1988.

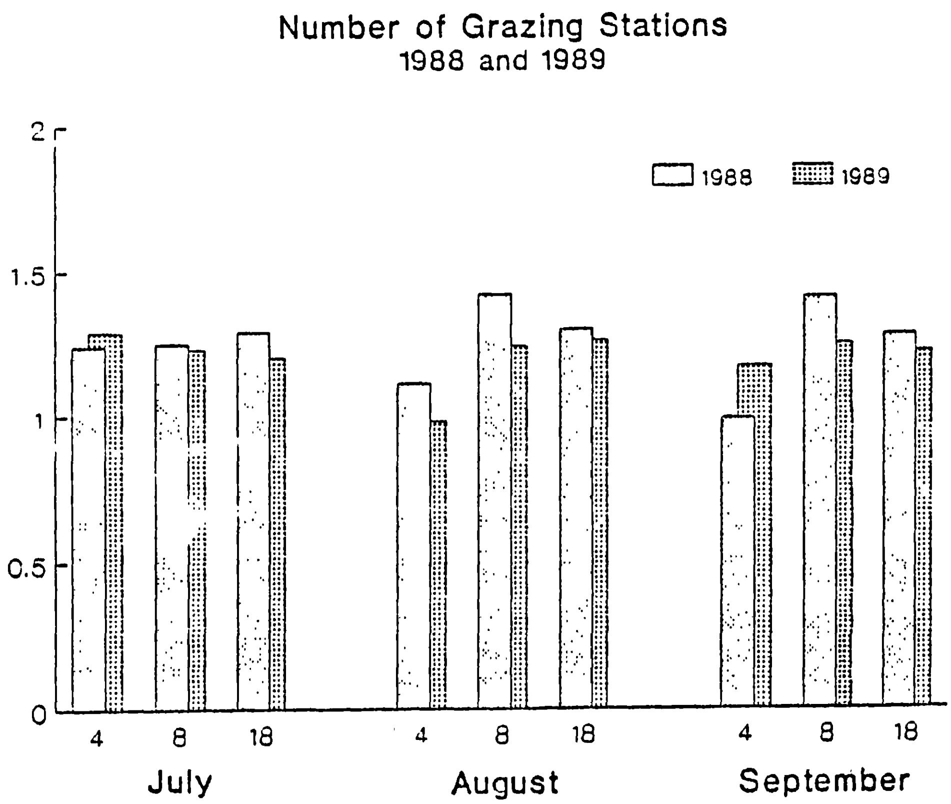

Fig. 28. Monthly mean number of grazing stations used during the 15-second observations by horses grazing 4-, 8-, and 18-hours on a picket in 1988 and 1989.

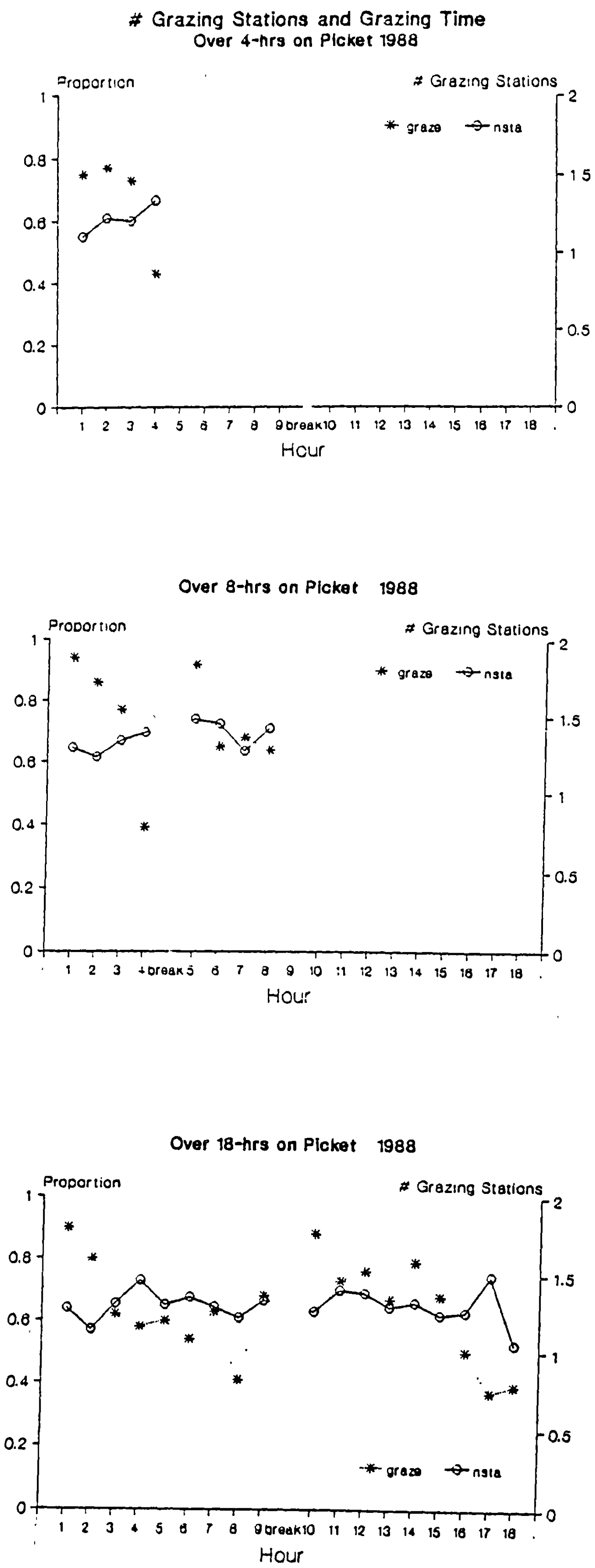

Fig. 29. Proportion of time spent grazing and number of grazing stations used over time on the picket by the 4-, 8-, and 18-hour horses while picketed in 1988.

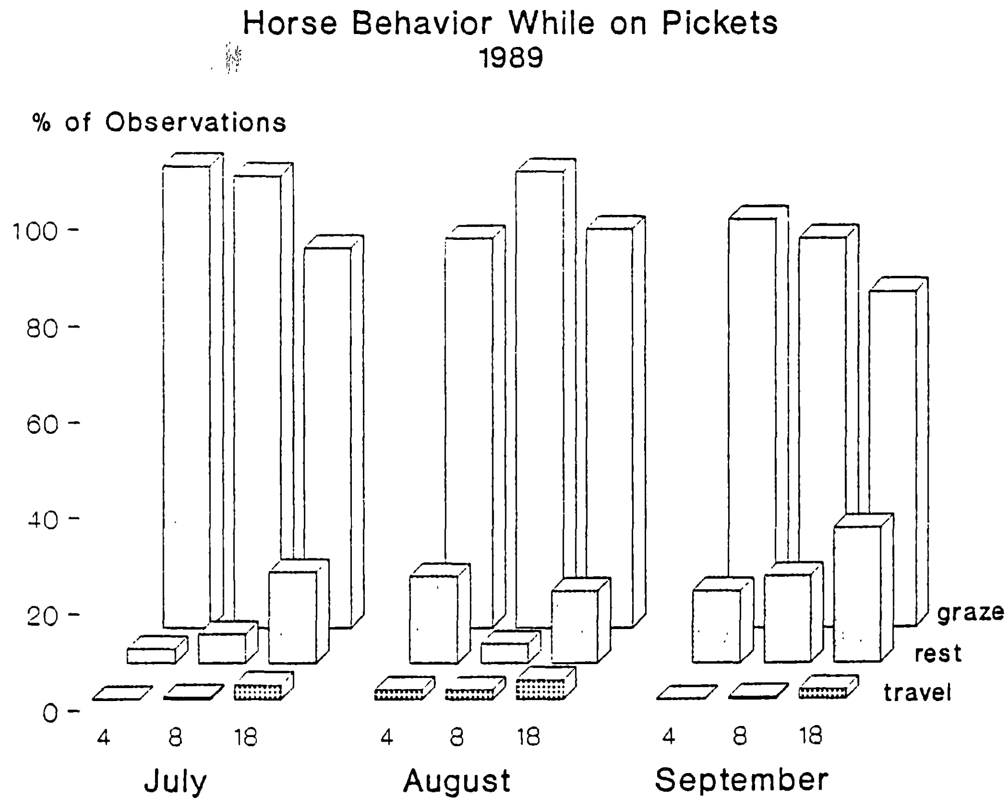

Fig. 30. Percent of picket time spent traveling, resting, or grazing by the horses in 1989.

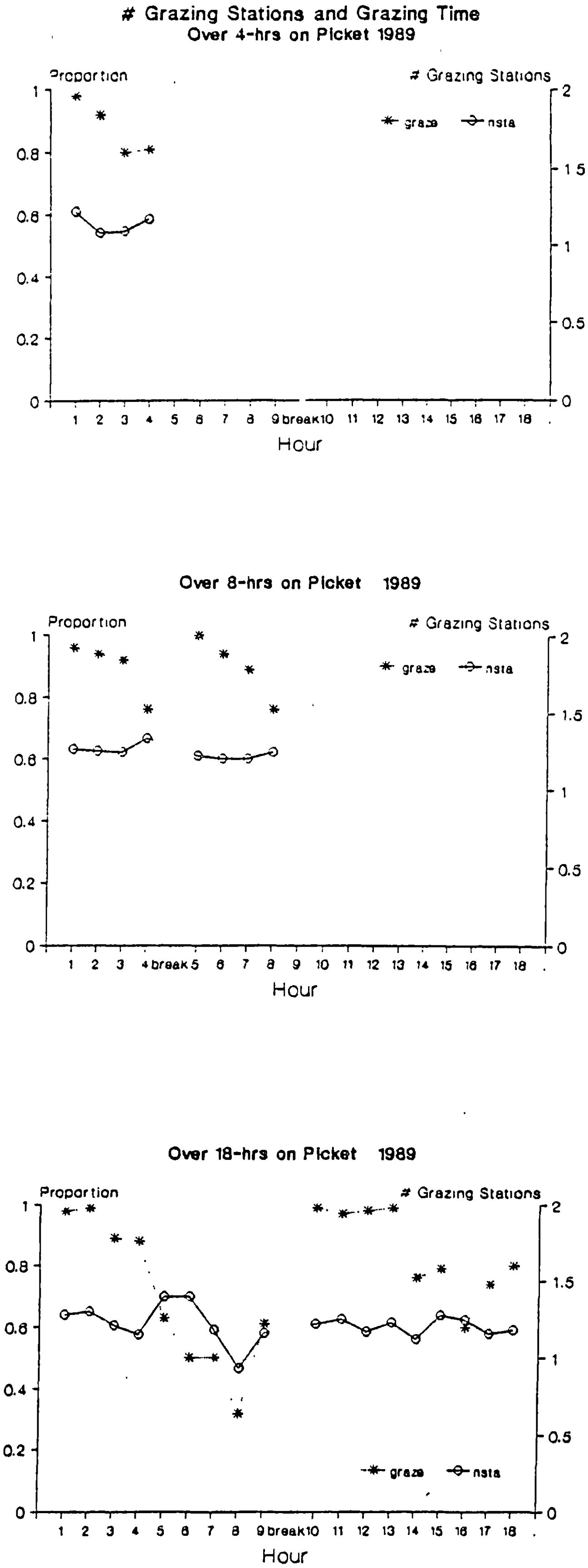

Fig. 31. Proportion of time spent grazing and number of grazing stations used over time on the picket by the 4-, 8-, and 18-hour horses while picketed in 1989.

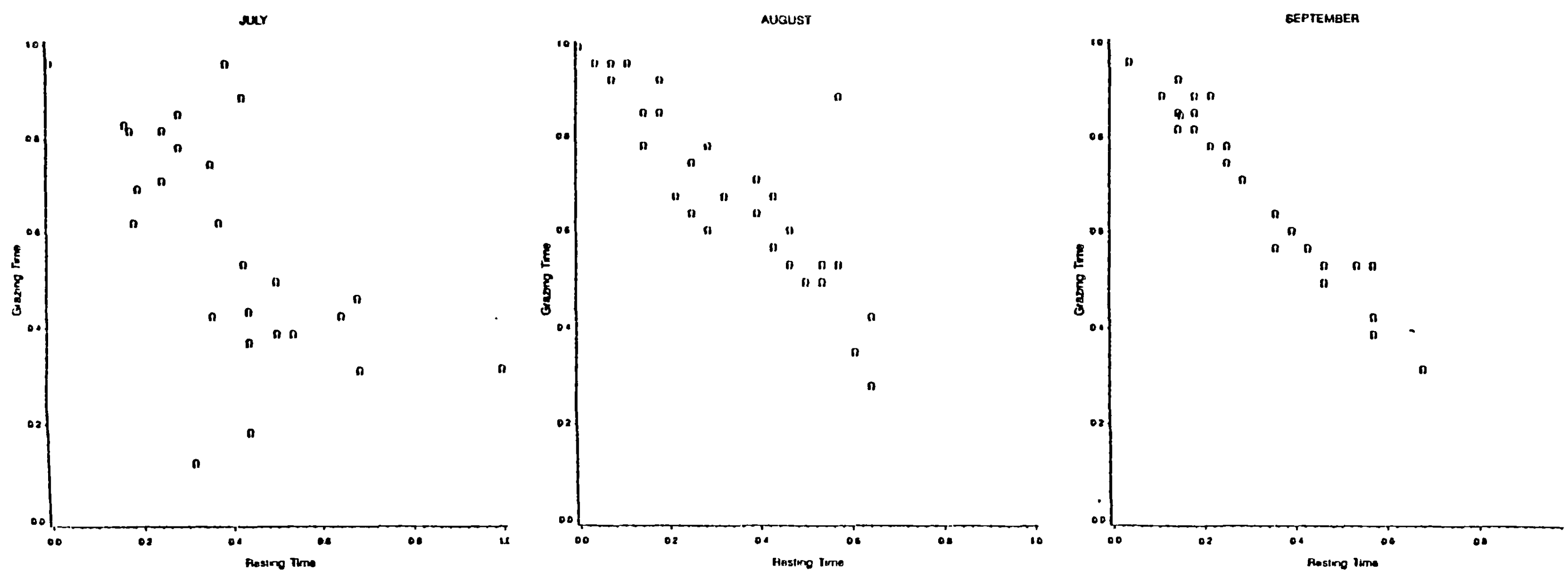

Fig. 32. Monthly correlation between grazing and resting time by horses on pickets in 1988 a) July, b) August, and c) September.

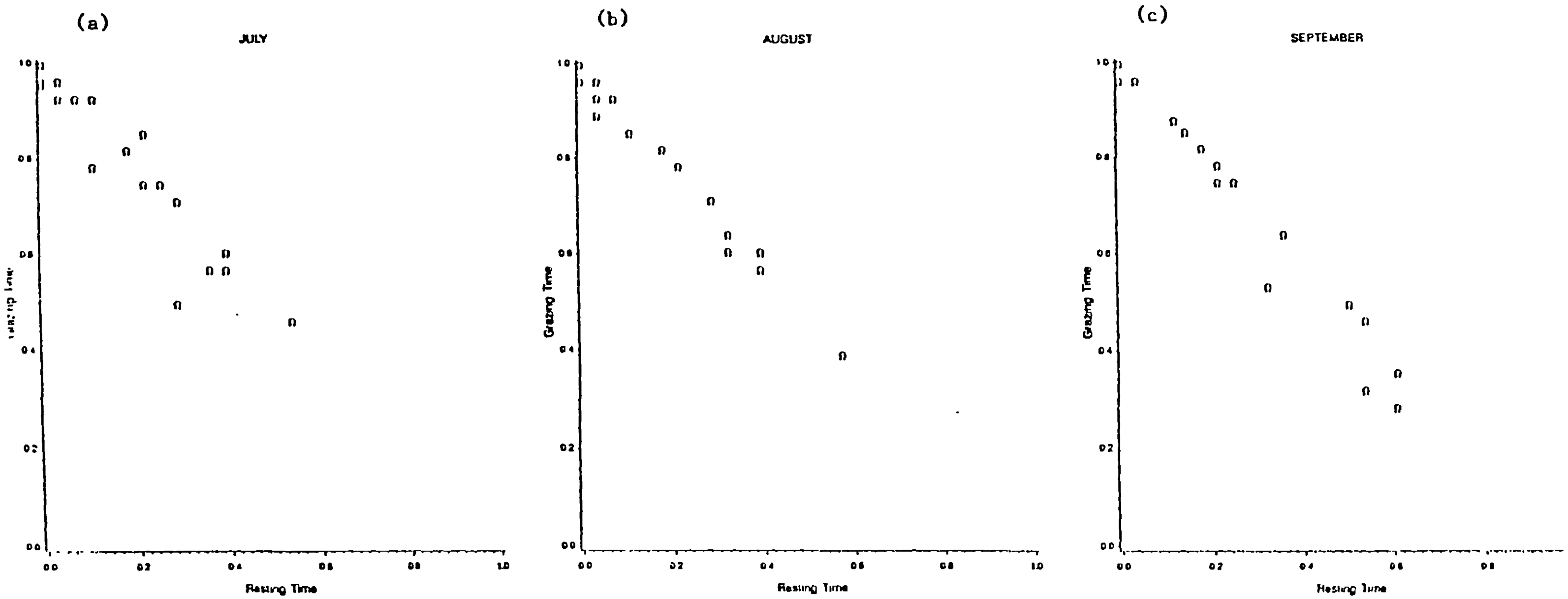

Fig. 33. Monthly correlation between grazing and resting time by horses on pickets in 1989 a) July, b) August, and c) September.

Grazed plant frequency data were only available from the 1989 trials. Grazed plant frequency increased as the hours of actual grazing increase (Fig. 34). Using stepwise regression, we analyzed proportion of plants used as a function of actual horse hours grazing, proportion of plants taller than 12 cm, and proportion of plants taller than 24 cm. Figures 35 and 36 illustrate the following best-fit equations.

$$\text{forbs} = 0.036 + 0.010H + 2.426T \quad \text{adj. R-squared}=.401$$

$$\text{grass} = 0.028 + 0.085H - 0.004H^2 \quad \text{adj. R-squared}=.567$$

Grass and forbs is the proportion of grasses or forbs grazed, H is the actual hours spent grazing, and T is the proportion of plants taller than 12 cm (height classes 4 and 5).

We thought that as the proportion of tall forbs increased, fewer may be grazed since they get bent by the picket rope or trampled and are then no longer "acceptable" to the horse as forage. This was not the relationship in our data (Fig. 35). However, we had less than 20% of the forbs taller than 12 cm. If there had been more tall forbs the relationship may have been different. The proportion of forbs grazed increased with increased horse hours spent grazing. This corresponds to the results of grazed plant frequency with duration on picket.

The proportion of grasses grazed was independent of grass heights, which is as expected since the grasses were less susceptible to trampling. The proportion of grasses grazed relative to horse hours grazing was non-linear, with a rapid increase initially then reaching a plateau (Fig. 36). After 12 hours grazing the horses had grazed most of the grass available, and additional time grazing would have to be on forbs or regrazing grasses already grazed. Therefore grazed plant frequency, in combination with forb heights, may be valuable to estimate forage available for packstock grazing and to quantify intensity of use.

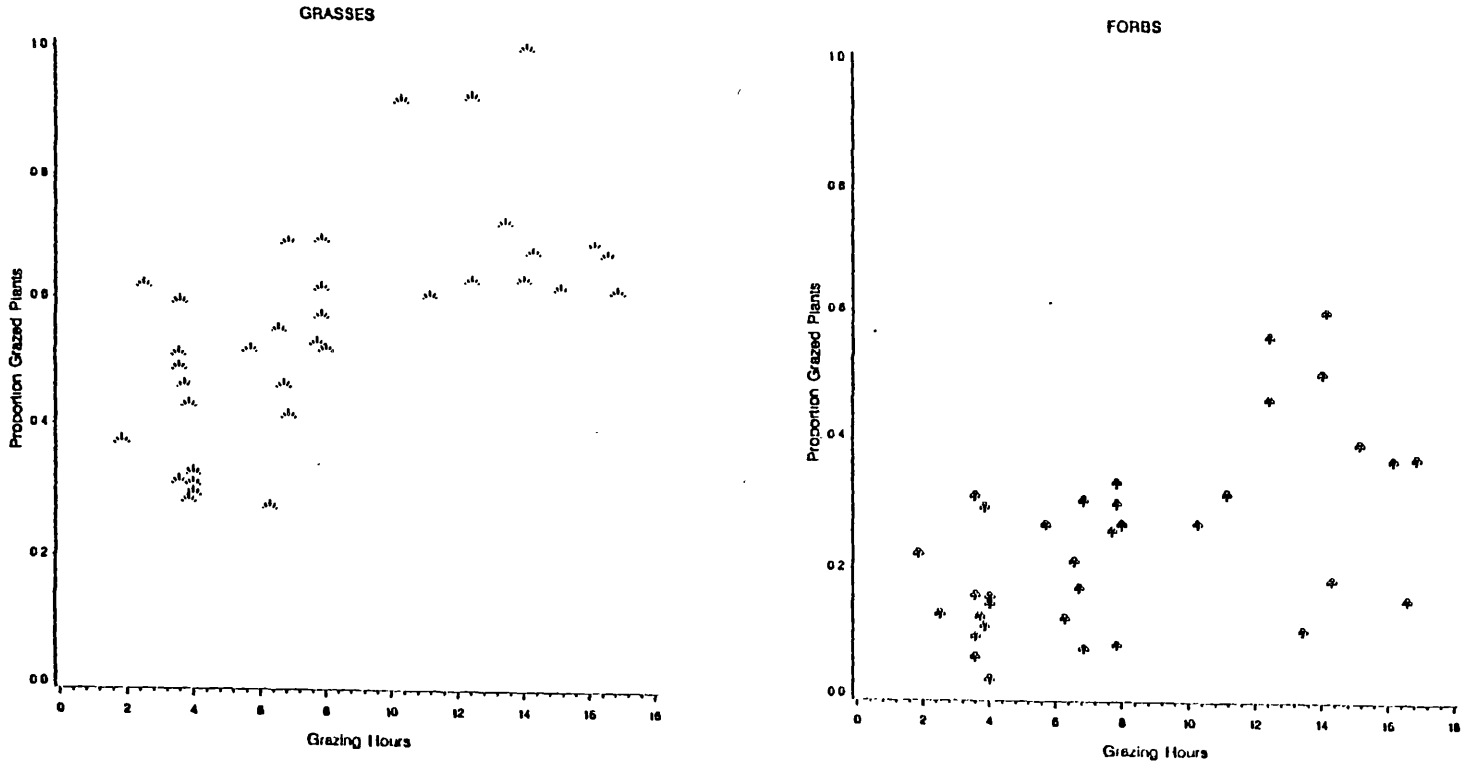

Fig. 34. Proportion of a) grasses, and b) forbs grazed relative to actual hours spent grazing in 1989.

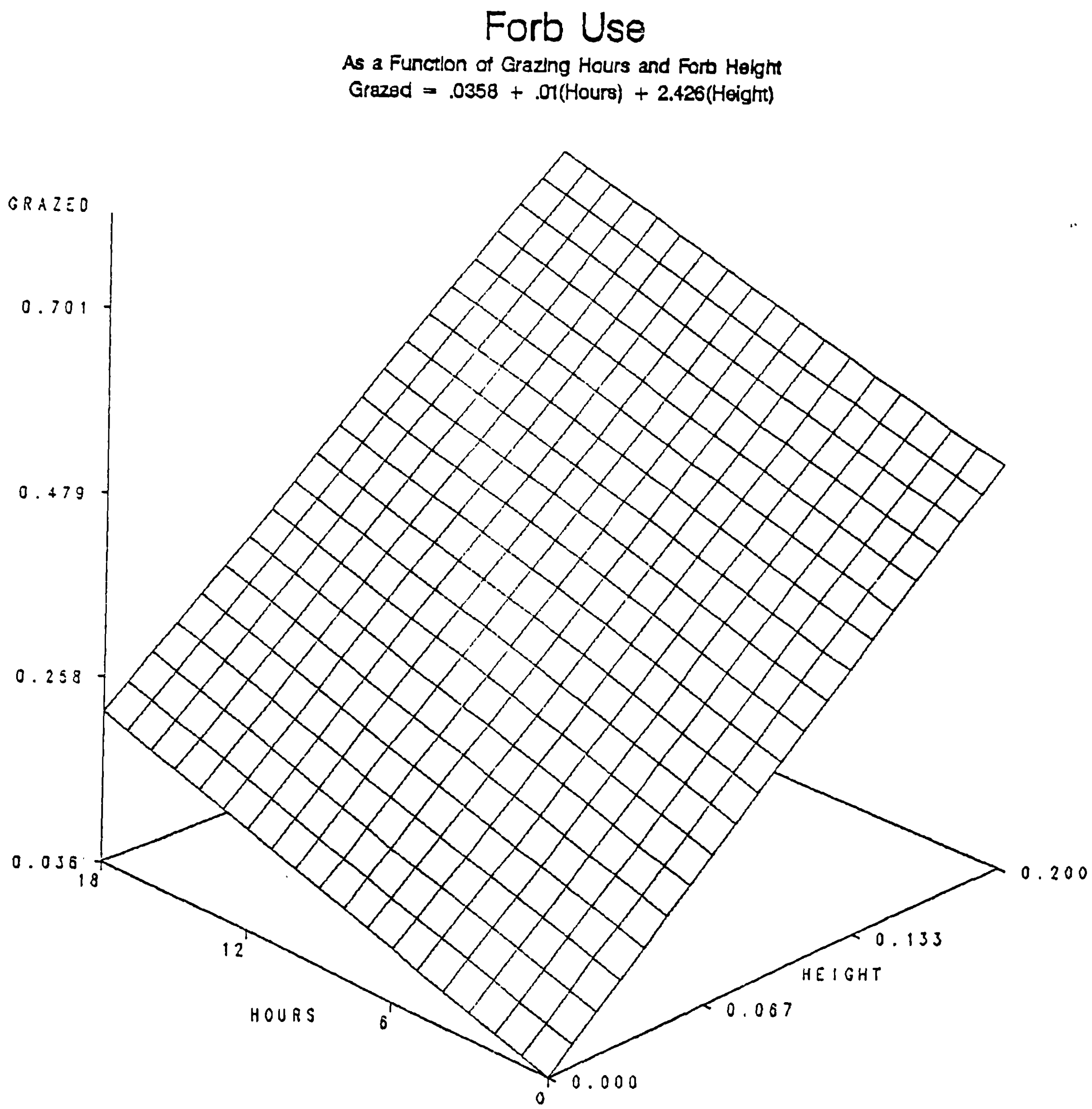

Fig. 35. The relationship between proportion of forbs grazed and actual hours spent grazing and proportion of forbs taller than 12 cm.

SUMMARY:

To prescribe management guidelines for packstock use, we must understand the effects of grazing on high elevation meadow plant communities. We have quantified the influence of a single grazing of three durations during each of three summer months and of three repeated grazing events on the same spot through the summer.

By grazing one time, for 4-, 8-, or 18-hours on a picket, horses have a measurable immediate impact on the picket circle. A high proportion of all plants were grazed and most plant material was reduced to less than 12 cm height after 8- and 18-hours grazing. In contrast, plant height on the 4-hour pickets was little different from the ungrazed circles. More grasses than forbs were grazed until horses were held on picket for 18 hours and forced to use more forbs. Repeated 4- and 8-hour grazing through the summer can have a cumulative impact as great as a single 18-hour grazing event.

Soil compaction, as measured in the top 1 cm was either increased or decreased depending on surface soil moisture. Hard, dry soils became dusty and soil compaction was decreased by hoof action, whereas moister soils could be compacted slightly. There was not a measurable cumulative increase in soil penetration resistance over the summer with repeated grazing.

There is some indication that the grazing treatments did influence the plant community one growing season later. Moderate to heavy grazing (8 hours, 18 hours, or repeated grazing) during the latter part of the summer's growing season may reduce vegetal cover and increase bare ground the following year, while grazing during July had little effect on ground cover. A reduction in grass stem numbers appeared to correspond to reduced vegetal cover. Grass and forb stem count changes did vary with duration and month of grazing. Eight- and 18-hours grazing during most months reduced grass stem counts the following year. Some July grazed circles had an increase in forb stem counts. Grazing early in the summer may benefit forbs, due to the negative impact on grasses. The August grazed circles had little change in forb numbers, except in 1988, when forage was limited and the horses used the forbs more heavily. Grazing in September reduced forb, as well as grass, stem counts. Repeated grazing through the summer reduced grass stem counts, but appeared to increase forb numbers.

The monthly differences in grass versus forb responses are due to the seasonal differences in flowering and susceptibility of the plant types to grazing. Plants are most sensitive to defoliation just before or during flowering (Blaisdell and Pechanec 1949, Mueggler 1967, Stout et al. 1981, Olson and Richards 1988). On the meadow we used, it

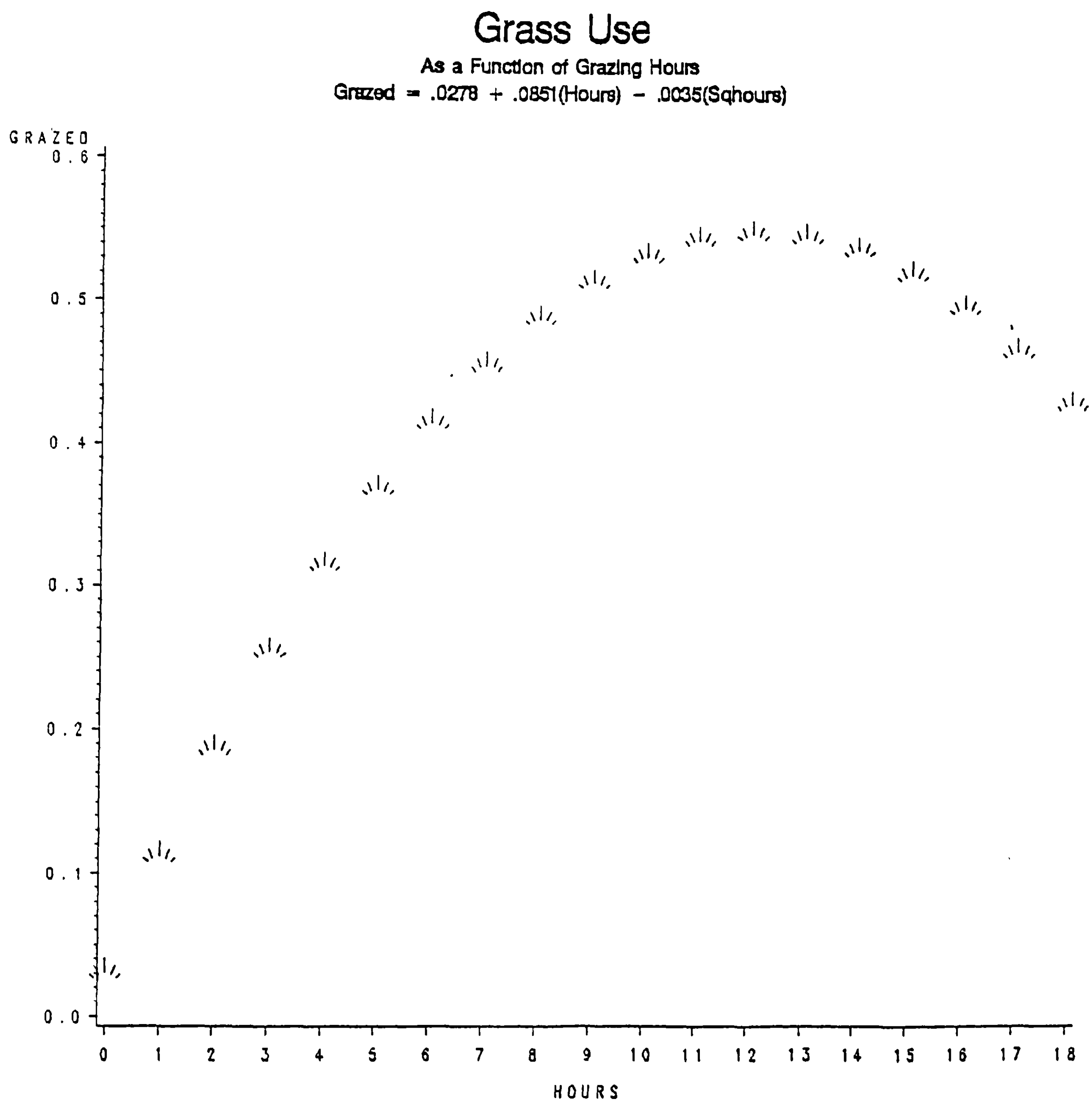

Fig. 36. The relationship between proportion of grasses grazed and actual hours spent grazing.

appeared that the grasses flowered earlier in the summer than the forbs, although many forbs may have flowered early in the growing season before we had access to the meadow. Therefore, mid-summer grazing defoliated the grasses when they were sensitive, and the forbs were not only used less but also defoliated at a time when they were less sensitive to grazing. This gave forbs an advantage the following growing season. By August the impact of defoliation on the forbs was countered by the reduced competition from the grasses, therefore their numbers stayed relatively constant. Grazing in September reduced grass stems because they were used heaviest, and reduced forb stems because many of the forbs were flowering at this time. Repeatedly grazing circles may benefit the forbs since the grasses are grazed heavily month after month. The longer or more heavily grazed an area becomes the more pronounced the negative effects of grazing become.

After two years of grazing under the same treatments, we would expect a stronger pattern of change in grass and forbs stems. However, we picketed horses in the meadows according to calendar dates rather than phenological stages of the plants. This potentially changes the competitive relationship between grasses and forbs being grazed. Since phenology is dirven by environmental factoes which vary spatially and temporally, competetive interactions vary annually. Yet the general pattern of increased forbs stems with July grazing, decreased forbs stems with September grazing, and decreased grass stems with any grazing is still somewhat evident. Averaging plant responses across species within grasses and forbs and grazing relative to calendar date rather than phenological stage can mask plant community response. Different species within a vegetation type flower at different times during a season, and this varies from year to year depending in growing conditions. This causes high variation, and shifts in species populations can go undetected for a number of years.

Patterns of plant height one growing season after grazing are similar to stem counts. Grazing reduced grass plant heights the following year. Mid- to late-summer grazing had a negative impact on the forbs. Repeated grazing reduced grass heights, but had little impact on forb heights. Height class data are difficult to use as an indicator of plant response. Changes in plant heights in response to grazing reported in other studies (Mueggler 1972, 1975, Trlica et al. 1977, Stout et al. 1980, Stout and Brooke 1987) would not have been large enough to put the plants into a different height class in our study. This is because our height classes were broad. For example, plants could be 23 cm tall one year, and 13 cm tall the next and remain in the same height class. We also

measured the tallest plant material rather than average plant height, which would have underestimated the overall plants' response.

Soil surface penetration resistance was not strongly influenced by our grazing treatments. No differences in soil surface compaction were detected one year after grazing. Even within the season, grazed circles equaled ungrazed circles within one month of recovery time. Although trails, campsites, and trailheads may experience high levels of use and compaction should be considered in those areas, we found that the animals' presence while grazing on a dry meadow at the levels we used, was not sufficient to influence soil surface compaction. However, at high levels of grazing, the impact on vegetation, ground cover, root growth, and water infiltration may interact with climatic forces on soil density. These indirect effects, rather than the physical impact of grazing animals may affect soil surface conditions on dry, high elevation meadows.

Horse grazing in high elevation meadows will have an immediate impact on their appearance. Horses prefer grasses over forbs, therefore continued moderate to heavy use may also influence the plant community one year after grazing, as grass stem densities decline. Forbs appear to benefit from mid-summer or repeated grazing thus minimizing vegetal cover loss. This would limit soil erosion but create a different floristic assemblage. However, our horses did use forbs when left on their pickets for 18-hours. At high levels of use and later in the summer, forbs were impacted by grazing an produced fewer stems the following year. Heavy use such as this would produce rapid changes in the meadows' appearance and biological productivity. The level of impact from grazing depends on the amount of forage available, which varies through the summer and from year to year. Consequently, unacceptable changes in the plant community may occur very slowly under moderate use (8 hour or repeated grazing). The rate or degree of change also varies with the experience of the horses being grazed. Horses comfortable with picketing and their surroundings will rest rather than pace when not grazing and may have less of an impact than those unused to picketing.

By controlling when, how long, and how frequent horses graze a meadow, packstock may be managed to maintain or change meadow plant communities. In principle, people have greater control over packstock than they do over livestock grazing, because packstock handling is intensive. The challenge of managing packstock is clearly defining the objectives of wildland management and then having recreationists handle their animals in a manner to accomplish those objectives

ACKNOWLEDGEMENTS: We appreciate the dedicated help by the many persons working as vegetation crew, wranglers, and camp cooks. This research was supported by funds provided by the Intermountain Research Station, Forest Service, U.S. Department of Agriculture, and the Montana Agricultural Experiment Station.

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